The Influence of Motor Skills on the Social Communicative Skills of Children with Autism Spectrum Disorder

by

Megan Iola MacDonald

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Kinesiology)
in The University of Michigan
2011

Doctoral Committee:

Professor Dale A. Ulrich, Chair
Professor Catherine Lord
Associate Professor Susan Brown
Associate Professor Wei Yun Chen

Acknowledgements

I would like to thank Dr. Dale Ulrich for providing me with this opportunity. His mentorship has been invaluable throughout my time at the University of Michigan. I would not be here without his generous encouragement, enthusiasm and support. I would like to thank Dr. Lord for allowing me to join the team at UMACC. I've felt so welcomed in both centers at all stages of this journey, and that speaks highly to the leadership of Dr. Ulrich & Dr. Lord. My entire dissertation committee has been so helpful. Thank you Dr. Susan Brown for your personal and professional advice, you always recognized when it was time to talk. Dr. Wei Yun Chen thank you so much for your support and allowing me to be a part of your class.

I would also like to thank the families and children who participated in this study. Their involvement contributed to more than just this dissertation. Their meaningful participation in research and their family's dedication to learning more will continue to help us explore how to best serve families with autism and other disabilities.

To my colleagues in the School of Kinesiology and at the University of Michigan Autism and Communications Disorders Center, thank you for your help, for teaching me how to do research and for showing me how to make it fun.

I would also like to thank the Rackham Graduate School, the Blue Cross Blue Shields Foundation of Michigan and the Office of Special Education Programs for funding this research and for helping to support my doctoral degree.

To my family, you're amazing—thank you.

Table of Contents

Acknowledgements ii

List of Tables vi

Chapter 1 Introduction 1

Models of early intervention 3

Dose, duration and content of early intervention 4

Social communicative intervention for school-aged children 6

Motor skills and children with autism spectrum disorders 9

Motor skills in young children with autism 10

Motor skills and school-aged children with autism 12

Brain based autism theories 13

Motor skills and social development in children with autism 15

The relationship of motor skills and social communicative skills in young children with autism 18

Chapter 2 The effect of motor skills on the calibrated severity of young children with autism spectrum disorder 35

Introduction 35

Method 39

Results 42

Discussion 45

Reference List 51

Table Captions 58

Chapter 3 The relationship of motor skills and the adaptive social and communicative behavior in young children with autism 65

Introduction 65

Method 71

Results 74

Discussion 80

Reference List 87

Table Captions 95

Chapter 4 The effect of motor skills on the social communicative skills of school aged children with autism spectrum disorders 104

Introduction 104

Method 109

Results 112

Discussion 113

Reference List 118

Table Captions 123

Chapter 5 Conclusion 131

Reference List 140

List of Tables

Table 2.1. Descriptive characteristics of the participants. 59

Table 2.2. Average motor skill difference variable based on the difference between the motor age equivalent score and the child's chronological age. 60

Table 2.3. Analysis of covariance (ANCOVA) for Fine Motor skills (standard scores) on Calibrated Severity of Autism. 61

Table 2.4. Analysis of covariance (ANCOVA) for categorical Fine Motor skills on Calibrated Severity of Autism. 62

Table 2.5. Analysis of covariance (ANCOVA) for Gross Motor skills (standard) on Calibrated Severity of Autism. 63

Table 2.6. Analysis of covariance (ANCOVA) for categorical Gross Motor skills on Calibrated Severity of Autism. 64

Table 3.1. Descriptive characteristics of the participants. 96

Table 3.2. Average motor skill difference variable based on the difference between the motor age equivalent score and the child's chronological age. 98

Table 3.3. Correlation analysis of dependent variables. 99

Table 3.4. Analysis of covariance (ANCOVA) for Fine Motor Skills on Adaptive Behavior Composite and Daily Living Skills. 100

Table 3.5. Analysis of covariance (ANCOVA) of Fine Motor on Adaptive Social and Communicative Behavior 101

Table 3.6. Analysis of covariance (ANCOVA) for gross motor skills on adaptive behavior composite and daily living skills. 102

Table 3.7. Analysis of covariance (ANCOVA) for Gross Motor Skills on Adaptive Social and Communicative Behavior 103

Table 4.1. Descriptive characteristics of the participants. 124

Table 4.2. Analysis of covariance (ANCOVA) for TGMD-2 total scores (raw scores) on Calibrated Severity of Autism. 125

Table 4.3. Analysis of covariance (ANCOVA) for TGMD-2 locomotor scores (raw scores) on Calibrated Severity of Autism. 126

Table 4.4. Analysis of covariance (ANCOVA) for TGMD-2 object control scores (raw scores) on Calibrated Severity of Autism. 127

Table 4.5. Analysis of covariance (ANCOVA) for TGMD-2 total scores (raw scores) on standardized social skills. 128

Table 4.6. Analysis of covariance (ANCOVA) for TGMD-2 locomotor scores (raw scores) on standardized social skills. 129

Table 4.7. Analysis of covariance (ANCOVA) for TGMD-2 object control (raw scores) on standardized social skills. 130

Chapter 1

Introduction

Autism spectrum disorder (ASD or autism) is a pervasive developmental disorder characterized by deficits in social skills, communication and repetitive or restricted interests (APA, 1994). Recent prevalence statistics suggest that 1 in every 110 children are diagnosed with ASD (CDC, 2011; Matson & Kozlowski, 2011). The continuous rise in diagnosis has been the focus of controversy and makes autism one of the most frequent childhood neurodevelopmental disorders (Fombonne, 2009; Matson & Kozlowski, 2011). Global screening for autism has been recommended by the American Academy of Pediatrics (AAP) for all young children twice by 24 months of age (AAP, 2007). National campaigns have been initiated by major research-driven autism authorities to educate parents on the early signs of ASD (CDC, 2011; Yirmiya & Ozonoff, 2007; Zwaigenbaum et al., 2005; Zwaigenbaum et al., 2007). Diagnostic measures have been standardized and can identify children with autism at a very young age (Gotham, Risi, Pickles, & Lord, 2007; Luyster et al., 2009; NRC, 2001). The benefit of early diagnosis allows families to enroll their children as soon as possible in early intervention which is the most widely accepted mode of behavioral treatment (Dawson et al., 2010; Eikeseth, 2009; Kasari et al., 2005; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010).

The necessity of early intervention for young children with autism has been clearly indicated (Dawson, et al., 2010; Eikeseth, 2009; Hayward, Eikeseth, Gale, & Morgan, 2009; Kasari, et al., 2005). Research has shown that early intervention improves daily living skills, academic performance and social communicative skills in young children with autism (Dawson, et al., 2010; Kasari, Freeman, & Paparella, 2006; Kasari, Gulsrud, et al., 2010; Lovaas, 1987; Rogers, Hall, Osaki, Reaven, & Herbison, 2000; Rogers et al., 2006; Wong & Kwan, 2010). Different treatment methods are used in early intervention, however the overarching concept is similar- to teach social communicative skills needed for successful daily living, with the purpose of generalizing these skills beyond the treatment setting (Kasari, et al., 2005; Laugeson, Frankel, Mogil, & Dillon, 2009; Machalicek et al., 2008).

Deficits in social communicative skills are the hallmark characteristic of autism and interventions for young children with autism are driven by these deficits (Dawson, et al., 2010; Elliott, Gresham, Frank, & Beddow, 2008; Gresham, Sugai, & Horner, 2001; Kasari, et al., 2005; McConnell, 2002; Rogers, et al., 2000). Although early intervention services are available for young children with autism, the content of early intervention varies across settings. For example, some services are focused on teaching discrete social communicative skills, such as making eye contact with a caregiver, improving requesting skills, and learning symbolic play skills (Kasari, et al., 2006; Lovaas, 1987). Other programs are focused on more global social communicative skills and offer an opportunity for parents to interact with their children in an environment that fosters play through providing toys and equipment intended to engage children in social play (Dawson, et al., 2010).

Models of early intervention

A number of studies have provided value pertaining to the importance of early intervention for young children with autism. One of the earliest documented and most widely cited early interventions for young children with autism is applied behavioral analysis (commonly known as ABA) established by Lovaas (1987). ABA consists of teaching children typical social communicative skills needed for daily living through positive reinforcement and repetition. Examples of social communicative skills taught include requesting, sharing, functional play (with construction toys or puzzles) and symbolic play. This intensive early intervention provides direct one-on-one instruction with an interventionist and is generally implemented for 40 hours per week. ABA research indicates that young children improve intellectual and educational functioning (Lovaas, 1987). Lovaas's study has had a significant impact on the content of early intervention and although this study resulted in children making significant social communicative gains, the absence of a control group made it hard to fully attribute these gains to the intervention itself. Since Lovaas's (1987) study more thorough research guidelines have been established for intervention research in autism (Lord et al., 2005). These guidelines include standardized methods of diagnosis and the use of randomized clinical trials (Gotham, Pickles, & Lord, 2009; Gotham, et al., 2007; Lord, 2000a; Lord, et al., 2005; Luyster, et al., 2009).

Subsequent studies have met the recommended research guidelines for early intervention and indeed positive social communicative changes have resulted (Dawson, et al., 2010; Kasari, et al., 2006; Kasari, Gulsrud, et al., 2010; Kasari, Paparella, Freeman, & Jahromi, 2008; Lord, et al., 2005). In an early intervention focused on teaching parents to implement behavioral strategies targeted at improving social communicative skills in their children, significant improvements were found (Kasari, et al., 2008). This intervention, which took place in the child's home, showed improvements of joint attention (non-verbal communication about a third entity with another person) and symbolic play skills (substituting one object for another) in young children with autism (Kasari, et al., 2008). Another in-home early intervention resulted in improvements of cognition, language and social development (Rogers, et al., 2000; Vismara, Colombi, & Rogers, 2009). This model of early intervention, the Denver model, combined the rigor of ABA with play-based routines that took place in the child's home (Rogers, et al., 2000). Recently, in a randomized control trial using a modified version of the same intervention found significant improvements in language, intellectual development and daily living skills (Dawson, et al., 2010).

Dose, duration and content of early intervention

Despite evidence on the effectiveness of early intervention, the content of early intervention differs based on the model implemented. Some interventions focus on discrete social communicative skills while other interventions focus on more global social communicative skills (Bruinsma, Koegel, & Koegel, 2004; Dawson, et al., 2010; Kasari, et al., 2006; Kasari, et al., 2008). Interventions with direct one-on-one instruction with the child and an interventionist have been implemented (Dawson, et al., 2010; Lovaas, 1987). The content of these programs often revolves around the child's typical daily routines and the social content within these routines, such as verbal and non-verbal requesting, play, and appropriate behavior (Dawson, et al., 2010; Lovaas, 1987). Other interventions have been implemented and target specific social communicative skills including joint attention and symbolic play (Bruinsma, et al., 2004; Kasari, et al., 2006). Although various models of early intervention exist and the fidelity of the implementation has been met, there are always slight differences across settings and interventionists (Dawson, et al., 2010; Kasari, et al., 2006; Kasari, Gulsrud, et al., 2010; Kasari, et al., 2008; Lovaas, 1987; Vismara, et al., 2009). Although the necessity of early intervention has been clearly indicated the specific content of early intervention has less agreement amongst the research community (Kasari, et al., 2005).

Best practice recommendations for early intervention include 1) immediate enrollment in early intervention when children are suspected of having autism spectrum disorder, 2) a minimum of 25 hours of direct one-on-one instruction weekly and 3) the opportunity to interact with age-matched typically developed peers (NRC, 2001). These guidelines have been formed based on consensus from experts (Lord, et al., 2005), but research regarding all aspects of these guidelines is ongoing. Parent-friendly methods of treatment are needed in order to meet the constraints some families face adhering to these recommendations (Meadan, Ostrosky, Zaghlawan, & Yu, 2009). One aspect of the recommendations that appears to be difficult to meet is the number of intervention hours. Twenty-five hours of one-on-one instruction has been recommended, while some interventions suggest more time spent in intervention other studies have shown improvements with less time than the recommendation (Lovaas, 1987; Vismara, et al., 2009). A modification of the Early Start Denver Model (Rogers, et al., 2000), offered a different dose of program treatment and implementing a model of intervention consisting of fewer hours (Vismara, et al., 2009). The focus of the intervention was to decrease the number of hours parents spent training with an interventionist. Using a multiple baseline approach, the authors found that one hour of didactic parent training significantly improved the children's social communicative skills through increased utterances with their parents, imitative behaviors and attentiveness (Vismara, et al., 2009).

With as little as 6 hours of parent training having positive effects on the child's social communicative behaviors there is a need to further explore program dose and how to maximize time spent in early intervention with the social communicative benefits (Anderson, Oti, Lord, & Welch, 2009; Vismara, et al., 2009). Consequently, aspects of treatment dose continue to be questioned (Eikeseth, 2009; Kasari, et al., 2005; Meadan, et al., 2009).

Social communicative intervention for school-aged children

Social skills become more complex as children get older and because of this the social scene becomes more difficult for older children with autism to navigate (Bauminger & Kasari, 2000; Bauminger, Soloman, et al., 2008; Bauminger, Solomon, et al., 2008; Bauminger, Solomon, & Rogers, 2010). Interventions and programs for older children with autism are driven by social communicative deficits (McConnell, 2002; Williams White, Keonig, & Scahill, 2007). Some of the behavioral strategies used for early intervention are also appropriate for social communicative interventions of school-aged children with ASD, when the appropriate age-related adaptations are made (Licciardello, Harchik, & Luiselli, 2008). Age-related adaptations can be made to strategies such as prompting and rehearsal, play-based activities, free-play activities, reinforcement, modeling, storytelling and direct instruction. These behavioral strategies are all examples of techniques that have been successfully implemented and used in social communicative interventions across different ages (Vaughn et al., 2003).

The content of social skills programs for school-aged children varies, but the basic premise of all interventions is to teach age-appropriate social skills needed for daily living (Bellini & Peters, 2008; Bellini, Peters, Benner, & Hopf, 2007). Both the content and delivery method of social skills programs range in nature. Social skills program delivery has included social stories, peer training, video feedback, modeling social skills, coaching social skills, behavior rehearsal, direct feedback, time-delayed feedback, positive reinforcement of appropriate social skills and both didactic and activity-based settings (Bellini & Peters, 2008; Bellini, et al., 2007; Chan, O'Reilly, & Leblanc, 2008; Chung et al., 2007; Liber, Frea, & Symon, 2008; Williams White, et al., 2007). The content of social skills programs typically focuses on general social skills needed for daily living, such as making eye contact, the to and fro use of conversation, making friends, understanding sarcasm and more generally social graces needed in forming friendships. However, in some social skills programs behavior management and more discrete skills need to be taught, including skills such as hygiene, money management, and other independent skills. It is generally agreed that social skill programs are a necessity for school-aged children with autism (Frankel et al., 2010; Laugeson, et al., 2009; McConnell, 2002).

To what extent these programs have led to improvements in social communicative skills remains unclear. For example, a meta-analysis by Bellini et al., (2007) found minimal improvements when school-based social skills programs were studied. Generally, it appeared that some immediate social improvements occurred during and immediately following the intervention, such as increases in positive behaviors and decreases in negative behaviors. Unfortunately long-term social change and generalizing learned skills over time were limitations (Bellini, et al., 2007).

When a social skills intervention was implemented where stories were read and each story targeted specific social skill, results indicated improvements in positive social behaviors such as children raising their hands to ask a question and decreases in negative behaviors such as inappropriate vocalizations (Chan, et al., 2008). Comprehensive questions based on the story were administered to judge understanding, followed by a role-play of a social situation to facilitate skill practice. Although the children in this study improved their social skills, the study was limited by a small sample size (N= 2). In another social skills intervention, lasting 12 weeks, peer trainers and video feedback were used in a more didactic program format (Chung, et al., 2007). The intervention found improvements in social skills such as increased appropriate conversation and decreased inappropriate conversations for some of the participants (Chung, et al., 2007). However improvements in social skills were not maintained three months following the intervention.

In summary, it is generally agreed that children with autism can benefit from social skills programs (McConnell, 2002; Williams White, et al., 2007). Reviews of social skills programs have had some positive outcomes, resulting in short-term success. Yet, there is less consistency in generalizing learned social skills beyond the treatment setting and over time (Bellini & Peters, 2008; Bellini, et al., 2007; Gresham, et al., 2001). Clearly, generalization is a goal in both practice and research. Recommendations for future research are aimed at improving social skill generalization (Lord, 2000b). These recommendations include the use of typically developed peers, natural settings (especially home and school), appropriate skill practice and ensuring an appropriate treatment "dose" (Lim, Kattapuram, & Lian, 2007; Lord, et al., 2005; Rogers, et al., 2000; Zwaigenbaum, et al., 2007). Although it is apparent that more work is needed to address the content of social skills interventions, it has been established that social skills interventions are a necessity for children with autism (Lord, 2000a; Lord, et al., 2005; McConnell, 2002). The specific content of social skills programs and how to best implement programs in order to adhere to social skill generalization is still under investigation. Indeed addressing the limitation of social skill generalization has been recommended as a priority in social skills interventions for school-aged children with autism (Gresham, et al., 2001; Lord, et al., 2005; Tutt, Powell, & Thornton, 2006).

Motor skills and children with autism spectrum disorders

One area that had not been given much consideration in the implementation of social skills programs is the impact of motor skills. In addition to the core characteristics of autism, social communication deficits, repetitive behaviors and restricted interests, children with autism frequently have motor skill deficits (Berkeley, Zittel, Pitney, & Nichols, 2001; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Green et al., 2002; Green et al., 2009; Leary & Hill, 1996; Lloyd, MacDonald, & Lord, 2011; Provost, Heimerl, & Lopez, 2007; Provost, Lopez, & Heimerl, 2007; Staples & Reid, 2009). In some of the original clinical descriptions of what is now called autism, Asperger attached considerable weight to motor clumsiness (Frith, 1991). Yet the current use of motor performance in autism diagnosis is embedded in gestures, stereotypies and imitation (Gotham, et al., 2009; Gotham, et al., 2007; Lord, 2000a; Luyster, et al., 2009). Some researchers have suggested that motor delays may be one of the earliest detectable signs of ASD and a cardinal feature of the disability (Carter et al., 2007; Fournier, et al., 2010; Sutera, Pandey, Esser, & Rosenthal, 2007; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). Undeniably, social communicative deficits remain the clearest indicator of autism in current practice (Lord, 2000a; Risi et al., 2006). Nevertheless, why children with autism display deficits in motor skills is a question of interest for many researchers in the field. How ASD manifests, and the neural system involvement is an ongoing area of study (Mostofsky, Burgess, & Gidley Larson, 2007; Mostofsky et al., 2009).

Motor skills in young children with autism

In children with ASD, between birth to 5 years, delayed motor milestones have been reported (Chawarska et al., 2007; Landa & Garrett-Mayer, 2006; Lloyd, et al., 2011; Teittelbaum, Teittelbaum, Nye, Fryman, & Maurer, 1998). These delays have ranged in nature, from delayed infant motor milestones such as moving from prone to supine to a later onset of walking and other discrete motor skills such as fine motor skills needed for building (construction blocks) and gross motor skills like alternating feet while taking the stairs. Retrospective video analysis indicated that motor delays early in development act as some of the initial signs of developmental concern in children eventually diagnosed with ASD (Ozonoff et al., 2008; Teittelbaum, et al., 1998). Teittelbaum, et al. (1998) found oral motor deficits as well as delays in motor milestones such as lying, righting, sitting, crawling and walking were present in young children with autism before the onset of social communicative deficits. The authors concluded that motor skill deficits might be some of the earliest signs suggesting autism.

It has been suggested that developmental delay, in children with ASD, contributes to deficits in motor skills (Ozonoff, et al., 2008). Although developmental delay may be a factor, it does not entirely explain motor skill deficits (Green, et al., 2009; Landa & Garrett-Mayer, 2006; Lloyd, et al., 2011). When children with autism were compared to children with language delay fine motor skill deficits were evident in children with ASD at 6 months of age and significantly worsened fine and gross motor skills were evident at 14 and 24 months of age (Landa & Garrett-Mayer, 2006). This study suggested early motor skill deficits as a potential characteristic which could distinguish children with autism and children with other developmental delays (language delay) (Landa & Garrett-Mayer, 2006). In a large clinical sample of young children with ASD (n=172, age 18-36 months) motor skills deficits existed while controlling for developmental delay (Lloyd, et al., 2011). The authors found gross and fine motor deficits became significantly worse as this group of young children aged, while controlling for visual receptive organization (non-verbal problem solving) (Lloyd, et al., 2011).

In addition to motor skills delays, other motor deficits in young children with autism have been found in gait and postural control. Children with autism between the ages of 4- 6 years old demonstrated a short step length and irregular body oscillations during walking, consistent with a less stable and more variable posture compared to typically developed controls (Vernazza-Martin et al., 2005). Younger children with autism displayed similar gait and postural control deficits compared to typically developed controls (children less than 2 years old), including abnormal heel-to-toe patterns, arm posturing and generally anomalies in movement including waddle walking (Esposito & Venuti, 2008).

Motor planning deficits have also been indicated in children with autism, such as translating motor intention into a global motor action. In these studies each motor task involved in the overall action was produced as an independent task (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). Similarly, Vernazza-Martin et al. (2005) found that young children with ASD had difficulty defining the goal of the motor action consistent with motor planning deficits, even when the task was adapted in a highly motivating fashion (a researcher playing in the areas that the children were performing in). While children understood the motor instruction, as evident by the action of moving toward the object, the final motor task could not be completed (play-based activities established in the playing area) indicating shortfalls in motor planning (Vernazza-Martin, et al., 2005). This study showed that children were able to perform individual motor tasks but unable to chain multiple motor tasks together into a more complex motor action, consistent with motor planning deficits.

Motor skills and school-aged children with autism

School-aged children with autism also have significant motor skill deficits. The Test of Gross Motor Development-2 (TGMD-2) assesses locomotor skills such as running, galloping, hopping, sliding, leaping and jumping as well as object control skills such as overhand throwing, striking, kicking, underhand rolling, dribbling and catching. All of these skills are considered essential skills needed in physical education and active play (Ulrich, 2000). Using this motor skill assessment children with autism displayed deficits in locomotor skills and object control skills in the poor and very poor range (Berkeley, et al., 2001; Staples & Reid, 2009; Ulrich, 2000). In a more recent study using the TGMD-2, findings corroborated previous research and reemphasized that children with autism could perform the motor skills, but in a less mature form (Berkeley, et al., 2001; Morin & Reid, 1985; Staples & Reid, 2009). For example, children could complete the skills, but the quality of motor skills was well below age-matched norms. Staples & Reid (2009) used two control groups, age-matched typically developed peers and children matched on the raw scores of the TGMD-2 (younger typically developed children). They concluded that children with autism had movement skills that were performed equivalent to children half of their chronological age (ie. 10 year old children with autism performed motor skills equivalent to a 5 year old). When 6- 10 year old children with high-functioning autism were compared to age-matched controls with a specific developmental disorder of motor function, greater motor deficits were found in the children with autism (Green, et al., 2002). In other words children with autism had weaker motor skills than children with a disability determined by motor skill deficits.

Motor planning deficits have been indicated in school-aged children with autism. Recent research has found that children with autism managed single motor tasks well, but deficits were present when chaining motor tasks into a global action (Fabbri-Destro, et al., 2009). More complex motor skills requiring a combination of actions, like object-control skills, were harder for children with ASD to execute.

Brain-based autism theories

Autism is considered a neurodevelopmental disorder; in fact recent statistics suggest that autism is the most frequent neurodevelopmental disorder (Fombonne, 2009). How brain development affects this pervasive and persistent disability is an ongoing area of research (Bartholomeusz, Courchesne, & Karns, 2002; Fombonne, Roge, Claverie, Courty, & Fremolle, 1999). Retrospective research indicates that brain growth accelerates sometime between 1- 3 years old, in children with autism (Hazlett et al., 2005). Fombonne et al. (1999) found that children with ASD between the ages of 2- 5 years old displayed Macrocephaly, head circumference greater than the 97th percentile, more frequently than typically developed controls. Using MRI, the cerebral brain volume of children with ASD was significantly greater than would be expected (Alyward, Minshew, Field, Sparks, & Singh, 2002; Sparks et al., 2002).

Using fMRI to study the connectivity within the motor circuits during simple motor tasks, decreased motor circuits were found in children with ASD (Mostofsky, et al., 2009). Compared to typically developing controls, children with autism displayed similar neural connectivity during rest, but differences were evident during a simple motor task, a finger tap exercise. Notably, the authors of this study discussed the brain area responsible for the procedural acquisition of motor skills may also be important in language and social development, both of which are deficient areas in children with ASD and core diagnostic characteristics (Mostofsky, et al., 2009).

Other brain-based theories related to autism and motor development include the mirror neuron hypothesis. Research in monkeys suggested that the mirror neuron system is a critical link between observation and action (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). There is also evidence to suggest that this system functions similarly in humans and may act as a neural basis that contributes to the social understanding of others actions and intentions (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Collectively, research suggests that neural strategies used to execute tasks are quite different or even absent in individuals with ASD during the observation of tasks. Although, it appears highly probably that this system impacts imitation, research is still ongoing.

Motor skills and social development in children with autism

Interventions and research for children with autism are driven by social communicative deficits, the core characteristics of autism. As such, home, school, clinical and community-based programs target improvement in these areas and are often packaged as early intervention or social skills programs (Bellini & Peters, 2008; Frankel, et al., 2010; Gresham, et al., 2001; Williams White, et al., 2007). It is rather well known that functional social skills are needed to form friendships, engage with adults, and participate in meaningful relationships (Bauminger, Soloman, et al., 2008; Bauminger, Solomon, et al., 2008). The social communicative deficits in children with ASD range in nature but overall acquisition, performance and fluency of social interactions are difficult (Gresham, et al., 2001; Kasari, et al., 2006; Kasari, et al., 2005; Kasari, et al., 2008).

Traditional social skills programs for school aged children with autism consist of direct instruction followed by practice in a group or individual treatment setting. Without basic social skills these children are at risk for being rejected by peers and missing out in other developmental milestones (Chamberlain, Kasari, & Rotheram-Fuller, 2007; McConnell, 2002). Research has shown that children with autism are capable of establishing and maintaining friendships when the social circumstances are ideal (Bauminger, Soloman, et al., 2008; Bauminger, Solomon, et al., 2008; Kasari, Locke, Gulsrud, & Rotheram-Fuller, 2010). However, the content of social communicative programs are not always meeting the needs of school-aged children with autism, especially generalizing learned skills beyond the program (Bellini & Peters, 2008; Bellini, et al., 2007).

For the most part, literature concerning the social skills of children with autism and literature concerning the motor skills of children with autism remain separate. Nonetheless, the role that motor skills play in social development or the role that social skills play in the development of proficient motor skills is an area needing further exploration. Autism symptomology is thought to be modifiable and peer relationships possible when a favorable environment has been provided (Bauminger & Kasari, 2000; Bauminger, Soloman, et al., 2008; Bauminger, Solomon, et al., 2008; Bauminger, et al., 2010; Pan, 2009).

In a large study of typically developed children, sport participation was a strong predictor of social competence (Howie, Lukacs, Pastor, Reuben, & Mendia, 2010). In this study children who participated in sports and clubs had higher social skills based on a standardized social skills index. Similarly in a group of children with disabilities, physical function and motor skills were important predictors of social competence- better physical function and motor skills were indicative of greater social competence (Kang et al., 2010). This study concluded that physical therapists should promote sport as an avenue to improve social skills for youth with disabilities. Based on the results of these studies, the need for social communicative programs for children with autism and the question of content that has been implicated in both early intention and social skills intervention, it seems reasonable that the relationship of motor skills and social skills should be explored further.

Various forms of practice and age-appropriate play are recommended in the literature as possible avenues to establish long-term social communicative success (Lord, et al., 2005). Clearly from the research that has been examined more work is needed in developing efficacious programs to teach both social skills and to facilitate learning motor skills (Lloyd, et al., 2011; McConnell, 2002; Staples & Reid, 2009). But, what is unknown is the impact or interaction that these skills have on each other.

Proficient motor skills are useful tools in environments that foster play, like the schoolyard (Ulrich, 2000). Children with ASD often lack functional and pretend play ideas and do better when play ideas are generated for them (Mastrangelo, 2009). Motor skills could be advantageous for these children to participate in age-based activities and games that are developmentally appropriate. The use of structured games, like sport, may provide good opportunities for social practice and teaching motor skills may also provide children with the functional play skills needed to participate in common playground activities and games (Mastrangelo, 2009).

It has been established that practicing skills in a naturalistic setting is valuable for skill generalization (Machalicek, et al., 2008; Pan, 2009; Williams White, et al., 2007). Functional motor skills may help optimize the use of naturalistic settings for children of all ages. Using individualized programs established through a multidisciplinary team is considered 'best practice' in social communicative interventions (Callahan, Henson, & Cowan, 2008). As a part of this multidisciplinary team, physical educators, physical therapists and occupational therapists may add an important additive piece by providing programs and training that facilitate learning age-appropriate motor skills.

Less proficient motor skills have been predictive of autism symptomology in young children (Sutera, et al., 2007; Teittelbaum, et al., 1998). But, how motor skills relate to social communication skills in children with ASD has not been studied. Intuitively, it might be thought that teaching age- appropriate motor skills could provide a child with the functional skills necessary to engage in play and facilitate practice with peers. In understanding this relationship first, we need to understand the impact of motor skills on the social communicative skills of children with autism. Recommendations for optimal social skills programs have been made in the literature for children with autism. First, programs need to be flexible enough to appropriately match the social deficit with the program and social practice is necessary to provide children with contextual significance and an opportunity to generalize the skills (Elliott, Malecki, & Demaray, 2001; Gresham, et al., 2001; Rao, Beidel, & Murray, 2008). This myriad of recommendations includes having a "tool box" of approaches and strategies (Sweizy, 2008).

The relationship of motor skills and social communicative skills in young children with autism

Although we are learning more about ASD every day the most widely cited and recommended mode of treatment is early intervention for the youngest children with autism (Dawson, et al., 2010; Kasari, et al., 2005; NRC, 2001). Early intervention has a direct focus on social communication skills, core diagnostic characteristics of ASD (NRC, 2001). For these young children this includes skills such as imitation, joint attention and play (functional and symbolic play skills) (Kasari, et al., 2005). Randomized control trials have clearly displayed that intensive early intervention significantly improves behavior in the social communicative domain as well as other aspects of autism symptomology (Dawson, et al., 2010; Kasari, Gulsrud, et al., 2010; Wong & Kwan, 2010). Improvements based on early intervention include IQ, language, adaptive behavior and autism diagnosis (ie. moving from ASD to PDD-NOS) (Dawson, et al., 2010; Lovaas, 1987). Although there is widespread agreement on the necessity of early intervention, there is less consistent agreement on early intervention content (Dawson, et al., 2010; Kasari, et al., 2005; Lovaas, 1987; Rogers, et al., 2000).

Descriptive studies have clearly demonstrated significant deficits in motor skills for young children with autism. Motor skill deficits have been acknowledged as potential diagnostic marker of autism early in development and a cardinal characteristic of the disorder (Fournier, et al., 2010; Rinehart & McGinley, 2010; Sutera, et al., 2007; Teittelbaum, et al., 1998). Deficits have been found in gait, postural control, motor planning, locomotor skills, objects-control skills and infant motor milestones (Berkeley, et al., 2001; Rinehart et al., 2006; Staples & Reid, 2009; Sutera, et al., 2007; Teittelbaum, et al., 1998; Vernazza-Martin, et al., 2005). However, very little has been studied and discussed in terms of how these motor skill deficits interact with social communicative development, a core characteristic and deficit area for individuals with ASD's.

The Denver model, an early intervention program for young children with autism, might be the closest intervention that successfully intertwines motor skills and social success; however, the impact of proficient motor skills has not been measured (Rogers, 2000). In fact, many of the social skills programs reviewed imply the use of games or activities to facilitate social learning. Some of the activities used in intervention require relatively proficient motor skills. Unmistakably, the emphases of the programs are social, but it is possible that these two domains are already intertwined, and this could be impacting children's success in these programs. In summary, teaching age-appropriate motor skills might add to a practitioners "tool box" of intervention strategies aimed at improving social success.

Although early intervention services are available for young children with autism, the rising prevalence of autism poses difficulty for service providers in adhering to the concurrent increase in early intervention service needs (Downs & Downs, 2010; Wise, Little, Holliman, Wise, & Wang, 2010). State early intervention services have experienced six month waitlists. There is a need to better understand accessible content for parents that is easily accessible (Meadan, et al., 2009). It is possible that motor skills may serve such a role.

The purpose of this dissertation is to understand the relationship of motor skills and the social communicative skills of children with autism spectrum disorder. These papers are arranged in three studies. The first study focuses on the relationship of gross and fine motor skills with the calibrated autism severity in a group of young children with autism (14- 33 months). Calibrated autism severity scores encompass a standardized measure of autism severity, and therefore a standardized measure of social communicative scores (Gotham, et al., 2009; Gotham, et al., 2007).

Study two explores the relationship of gross and fine motor skill with the daily living skills of young children with autism (14- 48 months). Daily living skills of young children with autism are often used as outcome measures in early intervention programs. Embedded in this assessment of daily living skills are other standardized scales of social communicative skills. This study aims to explore the relationship of fine and gross motor skills with standardized social communicative skills in a group of children with autism in the age range of early intervention.

Finally study three, explores how the functional motor skills of school-aged children (6- 15 years) with autism predict calibrated autism severity and standardized social skills (in an older group of children).

It is hypothesized that better motor skills predict better social communicative skills in children with autism. This relationship has not been explored in either young children with autism or school aged children with autism. Yet, deficits in both the motor and social communicative domain have been indicated. Therefore, it is possible that these domains are interacting. If these hypotheses hold true, these findings could impact the services of young children with autism and the addition of motor skill programs in early intervention services.

References

American Academy of Pediatrics (AAP). (2007).

Alyward, E., Minshew, N. J., Field, K., Sparks, B., & Singh, N. (2002). Effects of age on brain volume and head circumference in autism. *Neurology, 59*, 175-183.

Anderson, D., Oti, R., Lord, C., & Welch, K. (2009). Patterns of growth in adaptive social abilities among children with autism spectrum disorders. *Journal of Abnormal Child Psychology, 37*(7), 1019-1034.

American Phychiatric Association (APA). (1994). *Diagnostic and statistical manual for mental disorders, 4th Edition*, Washington, DC: American Psychiatric Association.

Bartholomeusz, H., Courchesne, E., & Karns, C. (2002). Relationships between head circumference and brain volume in healthy normal toddlers, children, and adults. *Neuropediatrics, 33*(239-241).

Bauminger, N., & Kasari, C. (2000). Lonliness and friendship in high-functioning children with autism. *Child Development, 71*(2), 447-456.

Bauminger, N., Soloman, M., Aviezer, A., Heung, K., Brown, J., & Rogers, S. (2008). Friendship in high-functioning children with autism spectrum disorder: mixed and non-mixed dyads. *Journal of autism and developmental disorders, 38*(7), 1211-1229.

Bauminger, N., Solomon, M., Aviezer, A., Heung, K., Gazit, L., Brown, J., et al. (2008). Children with autism and their friends: A multi-dimensional study of friendship in high-functioning autism spectrum disorder. *Journal of abnormal child psychology, 36*(2), 135-150.

Bauminger, N., Solomon, M., & Rogers, S. J. (2010). Predicting friendship quality in autism spectrum disorders and typical development. *Journal of Autism and Developmental Disorders, 40*, 751-761.

Bellini, S., & Peters, J. (2008). Social skills training for youth with autism spectrum disorder. *Child and adolescent psychiatric clinics of North America, 17*(4), 857-873.

Bellini, S., Peters, J., Benner, L., & Hopf, A. (2007). A meta-analysis of school-based social skills interventions for children with autism spectrum disorders. *Remedial and Special Education, 28*(3), 153-162.

Berkeley, S. L., Zittel, L. L., Pitney, L. V., & Nichols, S. E. (2001). Locomotor and object control skills of children diagnosed with autism. *Adapted Physical Activity Quarterly, 18*(4), 405-416.

Bruinsma, Y., Koegel, R. L., & Koegel, L. K. (2004). Joint attention and children with autism: A review of the literature. *Mental Retardation and Developmental Disabilities, 10*, 169-175.

Callahan, K., Henson, R. K., & Cowan, A. K. (2008). Social validation of evidence-based practices in autism by parents, teachers, and administrators. *J Autism Dev Disord, 38*, 678-692.

Carter, A., Black, D., Tewani, S., Connolly, C., Kadlec, M., & Tager-Flusberg, H. (2007). Sex differences in toddlers with autism spectrum disorders. *Journal of Autism and Developmental Disabilities, 37*(1), 86-97.

CDC. (2011).

Chamberlain, B., Kasari, C., & Rotheram-Fuller, E. (2007). Involvement or isolation? The social networks of children with autism in regular classrooms. *Journal of autism and developmental disorders, 37*, 230-242.

Chan, J., O'Reilly, M., & Leblanc, L. (2008). A social storiesTm intervention package for students with autism in inclusive classroom settings. *Journal of Applied Behavioral Analysis, 41*(3), 405-409.

Chawarska, K., Paul, R., Klin, A., Hannigen, S., Dichtel, L., & Volkmar, F. (2007). Parental recognition of developmental problems in toddlers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(1), 62-72.

Chung, K., Reavis, S., Mosconi, M., Drewry, J., Mathhew, T., & Tasse, M. (2007). Peer-mediated social skills training program for young children with high-functioning autism. *Research in Developmental Disabilities, 28*(4), 423-436.

Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., et al. (2010). Randomized, controlled trial of an intervention for infants with autism: The Early Start Denver Model. *Pediatrics, 125*(1), 17-23.

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motro events: a neurophysiological study. *Experimental Brain Research, 91*, 176-180.

Downs, R. C., & Downs, A. (2010). Practices in early intervention for children with autism: a comparison with the national research council recommended practices. *Education and training in autism and developmental disabilities, 45*(1), 150-159.

Eikeseth, S. (2009). Outcome of comprehensive psycho-educational interventions for young children with autism. *Research in Developmental Disabilities, 30*, 158-178.

Elliott, S., Gresham, F., Frank, J., & Beddow, P. (2008). Intervention validity of social behavior rating scales: features of assessments that link results to treatment plans. *Assessment for effective intervention, 34*(1), 15-24.

Elliott, S., Malecki, C., & Demaray, M. (2001). New directions in social skills assessment and intervention for elementary and middle school students. *Exceptionality, 9*(1&2), 19-32.

Esposito, G., & Venuti, P. (2008). Analysis of toddlers' gait after six months on independent walking to identify autism: A preliminary study. *Perceptual and Motor Skills, 106*, 259-269.

Fabbri-Destro, M., Cattaneo, L., Boria, S., & Rizzolatti, G. (2009). Planning action in autism. *Experimental Brain Research, 192*(3), 521-525.

Fombonne, E. (2009). A Wrinkle in Time: From early signs to a diagnosis of autism. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(5), 463-464.

Fombonne, E., Roge, B., Claverie, J., Courty, S., & Fremolle, J. (1999). Microcephaly and macrocephaly in autism. *Journal of Autism and Developmental Disabilities, 29*, 113-119

Fournier, K., Hass, C., Naik, S., Lodha, N., & Cauraugh, J. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Development Disorders, 40*(10), 1227-1240.

Frankel, F., Myatt, R., Sugar, C., Whitham, C., Gorospe, C. M., & Laugeson, E. (2010). A randomized controlled study of parent-assisted children's friendship training with children having autism spectrum disorders. *Journal of Autism and Developmental Disabilities, 40*(7), 827-842.

Frith, U. (1991). *Autism and Asperger syndrome*. Cambridge: Cambridge University Press.

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain, 119*, 593- 609.

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(5), 693-705.

Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for improved validity. *Journal of Autism and Development Disorders, 37*(4), 613- 627.

Green, D., Baird, G., Barnett, A. L., Henderson, L., Huber, J., & Henderson, S. E. (2002). The severity and nature of motor impairment in asperger's syndrome: A comparison with specific developmental disorder of motor function. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 43*(5), 655-668.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., et al. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine and Child Neurology, 51*(4), 311-316.

Gresham, F., Sugai, G., & Horner, R. (2001). Interpreting outcomes of social skills training for students with high-incidence disabilities. *Exceptional Children, 67*(3), 331-344.

Hayward, D., Eikeseth, S., Gale, C., & Morgan, S. (2009). Assessing progress during treatment for young children with autism receiving intensive behavioural interventions. *Autism, 13*(6), 613-633.

Hazlett, H., Poe, M., Gerig, G., Gimpel Smith, R., Provenzale, J., & Ross, A. (2005). Magnetic resonance imaging and head circumference study of brain size in autism. *Archieves of general psychiatry, 62*(1366-1376), 1366.

Howie, L., Lukacs, S., Pastor, P., Reuben, C., & Mendia, P. (2010). Participation in activities outside of school hours in relation to problem behavior and social skills in middle childhood. *Journal of School Health, 80*(3), 119-125.

Kang, L., Palisano, R., Orlin, M., Chiarello, L., King, G., & Polansky, M. (2010). Determinants of social participation- with friends and others who are not family members- for youths with cerebral palsy. *Physical Therapy, 90*(12), 1743- 1755.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young children with autism: a randomized controlled intervention study. *Journal of Child Psychology and Psychiatry, 47*(6), 611-620.

Kasari, C., Freeman, S., Paperella, T., Wong, C., Kwon, S., & Gultrud, A. (2005). Early intervention of core deficits in autism. *Clinical Neuropsychiatry, 2*(6), 380-388.

Kasari, C., Gulsrud, A., Wong, C., Kwon, S., & Locke, J. (2010). Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *Journal of Autism and Development Disorders, 40*(9), 1045-1056.

Kasari, C., Locke, J., Gulsrud, A., & Rotheram-Fuller, E. (2010). Social networks and friendships at school: Comparing children with and without ASD. *Journal of Autism and Developmental Disorders.*

Kasari, C., Paparella, T., Freeman, S., & Jahromi, L. (2008). Language outcome in autism: Randomized comparison of joint attention and play interventions. *Journal of consulting and clinical psychology, 75*(1), 125-137.

Landa, R., & Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders: A prospective study. *Journal of Child Psychology and Psychiatry, 47*(6), 629-638.

Laugeson, E., Frankel, F., Mogil, C., & Dillon, A. (2009). Parent-assisted social skills training to improve friendships in teens with autism spectrum disorders. *Journal of autism and developmental disorders, 29*, 596-606.

Leary, M., & Hill, D. (1996). Moving on: Autism and movement disturbance. *Mental Retardation, 34*(1), 39-53.

Liber, D., Frea, W., & Symon, B. (2008). Using time-delay to improve social play skills with peers for children with autism. *Journal of Autism and Development Disorders, 38*(2), 312-332.

Licciardello, C. C., Harchik, A. E., & Luiselli, J. K. (2008). Social skills intervention for children with autism during interactive play at a public elementary school. *Education and Treatment of Children, 31*(1), 27-37.

Lim, S., Kattapuram, A., & Lian, W. (2007). Evaluation of a pilot cilnic-based social skills group. *The British Journal of Occupational Therapy, 70*(1), 35-39.

Lloyd, M., MacDonald, M., & Lord, C. (2011). The motor skills of toddlers with autism spectrum disorders. *Autism*, 1-18.

Lord, C. (2000a). The Autism Diagnostic Observation Schedule- Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3).

Lord, C. (2000b). Commentary: Achievments and future directions for intervention research in communication and autism spectrum disorders. *Journal of Autism and Developmental Disorders, 30*(5).

Lord, C., Wagner, A., Rogers, S., Szatmari, P., Aman, M., Charman, T., et al. (2005). Challenges in evaluating psychosocial interventions for autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 35*(6), 695-708.

Lovaas, O. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychiatry, 55*(1), 3-9.

Luyster, R., Gotham, K., Guthrie, W., Coffing, M., Petrak, R., Pierce, K., et al. (2009). The Autism Diagnostic Observational Schedule- Toddler module: A new module of a standardized diagnostic measure of autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*, 1305-1320.

Machalicek, W., Oreilly, M., Beretvas, N., Sigafoos, J., Lancioni, G., Sorrells, A., et al. (2008). A review of school-based instructional interventions for students with autism spectrum disorders. *Research in Autism Spectrum Disorders, 2*(3), 395-416.

Mastrangelo, S. (2009). Play and the children with autism spectrum disorder: From possibilities to practice. *International Journal of Play Therapy, 18*(1), 13-30.

Matson, J., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 418-425.

McConnell, S. (2002). Interventions to facilitate social interactions for young children with autism: Review of available research and recommendations for educational intervention and future research. *Journal of Autism and Developmental Disorders, 35*(5), 351-372.

Meadan, H., Ostrosky, M., Zaghlawan, H., & Yu, S. (2009). Promoting the social and communicative behavior of young children with autism spectrum disorders: A review of parent-implemented intervention studies. *Topics in early childhood special education, 29*(2), 90-104.

Morin, B., & Reid, G. (1985). A quantitative and qualitative assessment of autistic individuals on selected motor tasks. *Adapted Physical Activity Quarterly, 2*(1), 43-55.

Mostofsky, S., Burgess, M. P., & Gidley Larson, J. C. (2007). Increased motor cortex white matter volume predicts motor impairment in autism. *Brain, 130*, 2117-2122.

Mostofsky, S., Powell, S., Simmonds, D., Goldberg, M., Caffo, B., & Pekar, J. (2009). Decreased connectivity and cerebellar activity in autism during motor task performance. *Brain, 132*(9), 2413-2425.

NRC. (2001).

Ozonoff, S., Young, G. S., Goldring, S., Greiss-Hess, L., Herrera, A. M., Steele, J., et al. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorders, 38*, 644-656.

Pan, C. (2009). Age, social engagement, and physical activity in children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 3*(1), 22-31.

Provost, B., Heimerl, S., & Lopez, B. R. (2007). Levels of gross and fine motor development in young children with autism spectrum disorder. *Physical & Occupational Therapy in Pediatrics, 27*(3).

Provost, B., Lopez, B. R., & Heimerl, S. (2007). A comparison in motor delays in young children: Autism spectrum disorder, developmental delay, and developmental concerns. *Journal of Autism and Developmental Disorders, 37*, 321-328.

Rao, P., Beidel, D., & Murray, M. (2008). Social skills interventions for children with aspergers syndrome or high-functioning autism: A reivew and recommendations. *Journal of Autism and Developmental Disorders, 38*(2), 353-361.

Rinehart, N., & McGinley, J. (2010). Is motor dysfunction core to autism spectrum disorder? *Developmental Medicine and Child Neurology*, 697.

Rinehart, N., Tonge, B., Bradshaw, J., Iansek, R., Enticott, P., & Johnson, K. (2006). Movement related potential in high-functioning autism and Asperger's disorder. *Developmental medicine and child neurology, 48*, 272-277.

Risi, S., Lord, C., Gotham, K., Corsello, C., Chrysler, C., Szatmari, P., et al. (2006). Combining information from multiple sources in the diagnosis of autism spectrum disorders. *Journal of the American Academy of Child & Adolescent Psychiatry, 45*(9), 1094-1103.

Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research, 3*, 131-141.

Rogers, S. (2000). Interventions that facilitate socialization in children with autism. *Journal of Autism and Developmental Disorders, 30*(5), 399-409.

Rogers, S., Hall, T., Osaki, D., Reaven, J., & Herbison, J. (2000). A comprehensive, integrated, educational, approach to young children with autism and their families *Preschool education programs for children with autism (2nd ed)*. Austin, TX: Pro-Ed.

Rogers, S., Hayden, D., Hepburn, S., Charlifue-Smith, R., Hall, T., & Hayes, A. (2006). Teaching young nonverbal children wtih autism useful speech: A pilot study of the Denver Model and PROMPT interventions. *Journal of Autism and Developmental Disorders, 36*, 1007-1024.

Sparks, B., Friedman, S., Shaw, D., Aylard, E., Echelard, D., & Artru, A. (2002). Brain structural abnormalities in young children with autism spectrum disorder. *Neurology, 59*, 184-192

Staples, K., & Reid, G. (2009). Fundamental movement skills and autism spectrum disorders.

Sutera, S., Pandey, J., Esser, E. L., & Rosenthal, M. A. (2007). Predictors of optimal outcome in toddlers diagnosed with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 98-107.

Sweizy, N. (2008). Bridging for success in autism: Training and collaboration across medical, educational, and community systems. *Child and adolescent psychiatric clinics of North America, 17*(4), 907-922.

Teitelbaum, P., Teitelbaum, O., Nye, J., Fryman, J., & Maurer, R. G. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Psychology, 95*, 13982-13987.

Teittelbaum, P., Teittelbaum, O., Nye, J., Fryman, J., & Maurer, R. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Psychology, 95*, 13982-13987.

Tutt, R., Powell, S., & Thornton, M. (2006). Educational approaches in autism: What we know about what we do. *Educational psychology and practice, 22*(1), 69-81.

Ulrich, D. (2000). *Test of Gross Motor Development* (2nd Edition ed.). Austin, Texas: Pro-Ed.

Vaughn, S., Kim, A., Morris Sloan, C., Hughes, M., Elbaum, B., & Sridhar, D. (2003). Social skills interventions for young children with disabilities. *Remedial and Special Education, 24*(1), 2-15.

Vernazza-Martin, S., Martin, N., Vernazza, A., Lepellec-Muller, A., Rufo, M., Massion, J., et al. (2005). Goal directed locomotion and balance control in autistic children. *Journal of Autism and Developmental Disorders, 35*(1), 91-102.

Vismara, L. A., Colombi, C., & Rogers, S. J. (2009). Can one hour per week of therapy lead to lasting changes in young childen with autism? *Autism, 13*(1), 93-115.

Williams White, S., Keonig, K., & Scahill, L. (2007). Social skills development in children with autism spectrum disorders: a review of the intervention research. *Journal of Autism Developmental Disorder, 37*(10), 1858-1868.

Wise, M. D., Little, A. A., Holliman, J. B., Wise, P. H., & Wang, J. (2010). Can state early intervention programs meet the increased demand of children suspected of having autism spectrum disorders? *Journal of Developmental and Behavioral Pediatrics, 31*(6).

Wong, V. C. N., & Kwan, Q. K. (2010). Randomized controlled trial for early intervention for autism: A pilot study of the autism 1-2-3 Project. *Journal of Autism and Developmental Disorders, 40*, 677-688.

Yirmiya, N., & Ozonoff, S. (2007). The very early autism phenotype. *Journal of Autism and Developmental Disabilities, 37*(1), 1-11.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience, 23*(2-3), 143-152.

Zwaigenbaum, L., Thurm, A., Stone, W., Baranek, G., Bryson, S., Iverson, J., et al. (2007). Studying the emergence of autism spectrum disorders in high-risk infants: methodological and practical issues. *Journal of Autism and Developmental Disorders, 37*(3), 466-480.

Chapter 2

The relationship of motor skills with the calibrated severity of young children with autism spectrum disorder

Introduction

Autism spectrum disorder (ASD or autism) is a pervasive developmental disorder characterized by deficits in social skills, communication and repetitive or restricted interests (American Psychiatric Association [APA], 1994). Recent prevalence statistics suggest that 1 in every 110 children are diagnosed with ASD (Matson & Kozlowski, 2011). Diagnostic measures have been standardized and can identify children with autism as early as 1 year of age (Gotham, Risi, Pickles, & Lord, 2007; Luyster et al., 2009; NRC, 2001). Unfortunately the continuous rise in diagnosis makes autism one of the most frequent childhood neurodevelopmental disorders (Fombonne, 2009).

The most widely cited and recommended mode of treatment for young children with autism is early intervention, which has a direct focus on improving social communicative skills such as imitation, joint attention and play (functional and symbolic play skills) (Dawson et al., 2010; Eikeseth, 2009; Hayward, Eikeseth, Gale, & Morgan, 2009; Kasari, Freeman, & Paparella, 2006; Kasari et al., 2005; NRC, 2001). Improvements based on intensive early intervention have included improved IQ, language, adaptive behavior and autism diagnosis (ie. moving from autism, to pervasive developmental disorder-not otherwise specified [PDD-NOS]) (Dawson, et al., 2010;

Kasari, et al., 2006; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Wong & Kwan, 2010).

Although autism interventions are driven by deficits in social communication skills, young children with autism frequently have motor skill deficits (Green et al., 2009; Leary & Hill, 1996; Lloyd, MacDonald, & Lord, 2011; Provost, Heimerl, & Lopez, 2007; Provost, Lopez, & Heimerl, 2007; Staples & Reid, 2009). Movement research in the past has focused stereotypies and imitation (Levinson & Reid, 1993; Luyster, et al., 2009; Reid, O'Connor, & Lloyd, 2003). However, more recent research has shown that motor deficits for children with autism are present (Lloyd, et al., 2011; Staples & Reid, 2009; Teittelbaum, Teittelbaum, Nye, Fryman, & Maurer, 1998; Vernazza-Martin et al., 2005).

Early signs of motor deficits such as delayed motor milestones (for example, walking) may be first noticed by parents who later receive a diagnosis of autism for their child (Chawarska et al., 2007). Empirical research has confirmed that early motor delays are present in children with autism at a young age (as young as 6 months of age) (Landa & Garrett-Mayer, 2006; Lloyd, et al., 2011; Teittelbaum, et al., 1998). Delayed motor milestones such as lying, righting, sitting, crawling and walking as well as oral motor deficits have been described and it has been suggested that early motor delays may act as some of the first signs of developmental concern in children eventually diagnosed with autism (Teittelbaum, et al., 1998). Early motor deficits have even been indicated as a potential early diagnostic marker of autism (Teittelbaum, et al., 1998).

Deficits in motor planning also exist in children with autism. Fabbri-Destro et al. (2009) reported that children had difficulty translating motor intentions into a global motor action where each motor task involved in the overall action was treated as an independent task. Deficits in gait and postural control have been indicated through shorter step length, irregular body oscillations, abnormal heel-to-toe patterns, abnormal arm posturing and generally higher frequencies of anomalies in movement including waddle walking (Esposito & Venuti, 2008; Vernazza-Martin, et al., 2005).

While motor skills deficits are present in young children with ASD the primary focus of early intervention is based on improving social communication deficits, a phenotypic characteristic of autism. Consequently, very little has been discussed in terms of how motor skill deficits interact with the core characteristics of autism spectrum disorder.

Basic motor skills early in life could provide a solid foundation for the components of early intervention to manifest positively, in other words provide children with the foundational skills needed to move towards an optimal outcome (Helt et al., 2008; Sutera, Pandey, Esser, & Rosenthal, 2007). Yet, this suggestion has not been studied directly. Although the modality of early intervention varies, the basis of early intervention revolves around social communicative skills through active play (Dawson, et al., 2010; Kasari, Paparella, Freeman, & Jahromi, 2008; Rogers, Hall, Osaki, Reaven, & Herbison, 2000). For the most part, deficits in social skills, communication and repetitive or restrictive interests, the core characteristics of autism, have been studied without careful consideration of deficits in motor skills. Motor skills have just started to gain attention in descriptive autism research, yet the importance of motor skills in young children with autism has not been explored, especially in connection to the core behavioral characteristics of autism. Early intervention is focused on active play which often requires relatively proficient motor skills (Dawson, et al., 2010; Lloyd, et al., 2011; Makrygianni & Reed, 2010).

The importance of standardized assessments in measuring social communicative change has been clearly indicated (Matson & Wilkins, 2009). Recently new standardized method of assessment for autism severity have been published (Gotham, Pickles, & Lord, 2009). The Autism Diagnosis Observation Schedule (ADOS) is widely accepted as the 'gold-standard' in autism diagnosis (Lord, 2000; Luyster, et al., 2009; Matson & Sipes, 2010). The ADOS is a semi-structured interview designed for individuals suspected of having autism spectrum disorders and consists of "presses" (standardized activities performed throughout the assessment) designed to elicit social interaction, communication and play, through conversation, play-based activities and the imaginative use of materials (Lord, 2000). The ADOS generates diagnostic algorithms with thresholds set for autism and broader autism spectrum/ pervasive developmental disorder (Lord, 2000). New revised algorithms for the ADOS modules 1, 2 and 3 have been published with stronger specificity and sensitivity (Gotham, et al., 2007). These revised algorithms moved the ADOS closer to a measure of autism severity (Gotham, et al., 2007) and recently, standardized scores in calibrated severity using raw scores from the new revised algorithms of the ADOS were published (Gotham, et al., 2009). Calibrated autism severity scores have been indicated as optimal for comparisons of assessments across time (and age), and to identify different trajectories of autism severity independent of verbal IQ (Gotham, et al., 2009).

Previously, autism 'severity' was subjective and frequently based on language delay, cognitive functioning, behavioral issues and raw scores on the ADOS were used

(Lovaas, 1987; Sutera, et al., 2007). However, none of these outcome variables constitute valid and reliable methods of severity assessment, per se (Gotham, et al., 2009). The calibrated severity scores represent core deficits specific to the social communicative domain and repetitive and restricted interests, as they are mapped based on ADOS raw scores (Gotham, et al., 2009). Understanding how motor skills relate to severity may help to better understanding motor skill deficits in relation to autism as a whole, and further how motor skills may influence the core characteristics of autism.

The purpose of this study is to determine the relationship of motor skills in the calibrated autism severity of a group of young children with autism.

Method

Participants. The Medical Institutional Review Board at the University of Michigan approved all methods and procedures for this study. Young children with ASD, pervasive developmental disorder-not otherwise specified (PDD-NOS) and non-ASD between the ages of 12- 33 months were recruited from early intervention studies and clinical referrals to the University of Michigan Autism and Communicative Disorders Center (UMACC), an autism clinic in Chicago and a University autism clinic in North Carolina. Generally, children were recruited through autism support groups, study flyers and referrals from pediatricians and teachers were informed of the research study when visiting the autism clinic. All participants in this study (N= 159) had a confirmatory diagnosis of autism (ASD), PDD-NOS or non-ASD (developmental delay). Diagnosis was determined by standardized algorithms established from the Autism Diagnostic Observation Schedule (Gotham, et al., 2007).

Measurements

Child Diagnostic Measures. All participants were administered the ADOS (Lord, 2000) or its precursor, the Pre-Linguistic Autism Diagnostic Observation Schedule (PL-ADOS) (DiLavore, Lord, & Rutter, 1995), in order to acquire diagnostic information through direct observation of the children by a trained clinician. The participants at the University of Michigan Autism and Communicative Disorders Center were administered the Toddler module of the ADOS (Luyster, et al., 2009). Each member of the research clinical teams, at all centers (Michigan, Chicago and North Carolina), established inter-rater reliability exceeding 80% exact agreement (kappa>0.60) on codes for the PL-ADOS, ADOS, and Toddler module for three consecutive administrations before the studies began. Reliability was maintained over time through consensus coding of approximately every sixth administration with a second rater who was blind to referral status.

Measurement of Developmental Level. The Mullen Scales of Early Learning (MSEL) was used to assess cognitive development (Mullen, 1995). This test of development provides reliable and valid information for children from birth to 68 months of age. The subscales of the MSEL are organized into 5 domains: gross motor, fine motor, visual reception (nonverbal problem solving), receptive language, and expressive language. An early learning composite score is derived from the fine motor, visual reception, receptive language and expressive language scales.

Motor Skill Measurement. The gross motor scale of the MSEL was used to assess gross motor skills (Mullen, 1995). This scale was administered in a clinical setting with other developmental and diagnostic measures at baseline and prior to random group assignment. A gross motor standard score was used for analysis. Since, standardized T-scores do not provide sub-scores below 20, an age equivalent scores calculated (see Table 2.1). Standard scores from the gross and fine motor subtests of the MSEL were used to assess the gross and fine motor skills of the children with ASD.

Data Reduction. All examiners strictly adhered to the standardized procedures outlined in each respective test manual. As indicated in the measurement description of instruments, research reliability and inter-rater reliability was established for the ADOS. Autism cut-off was based on up-to-date revised standardized algorithms (Gotham, et al., 2007). These algorithms included scores based on social communication, repetitive and restricted interests and stereotyped behaviors. Calibrated autism severity was calculated based on standardized algorithms (Gotham, et al., 2009). Assessments were conducted by experienced administrators who were familiar in working with young children with autism. The MSEL was also administered to all participants- descriptive scores from the MSEL included an age difference score (see Table 2.2) (Mullen, 1995). The age difference score was calculated based on the chronological age of the participant and their subsequent gross motor and fine motor age equivalent. The motor scales are standardized for children birth to 33 months. Standardized motor scores were used for analysis in this study as the sample consisted of children 33 months and younger (Carter et al., 2007). Descriptive characteristics of the sample included age, gender and ethnicity. A diagnosis of autism, PDD-NOS or non-ASD was obtained and reported based on the participant's standard ADOS score (Lord, 2000; Luyster, et al., 2009); standard developmental levels are reported based on the standard measures of the MSEL (Mullen, 1995).

Data Analysis

Data analysis tested the relationship of gross and fine motor skills measured by the gross motor scale and the visual expressive (fine motor) scale of the Mullen Scales of Early Learning (MSEL) with the calibrated severity of autism spectrum disorder as measured by the calibrated severity algorithms (Gotham, et al., 2009; Gotham, et al., 2007). A linear regression model used the gross motor and fine motor scores on the MSEL as the dependent variables to test the relationship motor skills with the calibrated severity scores of autism. Age and non-verbal problem solving (as based on the visual receptive organization subscale of the MSEL) were also included in this model.

Results

A total of 159 children with a confirmed diagnosis of ASD (n= 110), PDD-NOS (n= 26) and Non-ASD (n=23) were included in this study (mean age= 27.6 months, ±4.6 months). Descriptive characteristics of this sample can be found in table 2.1. As shown in table 2.2 MSEL standard scores revealed the presence of fine and gross motor deficits. A frequency analysis revealed a high proportion of the sample scored within the basal norm range (a standard T score of 20). Fifty percent (50.7%) of the sample scored the basal norm for the gross motor scale of the MSEL and twenty-four percent (24.5%) of the sample scored within the basal norm range of the fine motor scale of the MSEL.

Average age equivalent scores are reported for all subscales of the MSEL (see Table 2.1). For descriptive purposes a gross motor difference variable was calculated- this variable quantifies the amount of motor delay in months regardless of chronological age (see Table 2.2). The same formula was used to compute a fine motor difference score for the children's fine motor skills (Table 2.2). Based on the age difference calculation, children were performing 6.9 months behind norm-referenced gross motor skills and 9.5 months behind norm-referenced fine motor skills of typically developed children.

Influence of Fine Motor Skills on Calibrated Severity

A regression analysis was performed on the calibrated severity scores using the predictor's of standardized fine motor scores, age (in months) and visual receptive organization (non-verbal problem solving). This initial analysis showed evidence that fine motor skills and non-verbal problem solving were strong predictors of calibrated severity in autism. Collinearity diagnostics suggested that age could be dropped from this model based on its strong relationship to visual receptive organization (non-verbal problem solving). This preliminary analysis informed analysis of covariance (ANCOVA) fitting standard fine motor skills, non-verbal problem solving, gender, ethnicity and autism diagnosis (age was dropped based on collinearity diagnostics). There were no significant interactions. ANCOVA showed that both fine motor skills and autism diagnosis were significant predictors of autism severity ($p \leq 0.001$ and $p < 0.001$) (Table 2.3). Since standard scores were not well distributed a visual binning analysis was conducted, distributing fine motor T scores (based on the MSEL) into categorical data of low, medium and high motor scores. ANCOVA performed on the categorical fine motor skills (based on visual binning) revealed that fine motor skills were significant predictor of calibrated severity of autism (Table 2.4). This model also indicated that diagnosis was a predictor in calibrated severity.

Fine motor skills were a significant predictor of calibrated severity scores ($p \leq 0.01$). This final model indicated that children with worse motor skills had a higher autism severity.

Influence of Gross Motor Skills on Calibrated Severity

A preliminary analysis of standardized gross motor skills (based on the MSEL), non-verbal problem solving and age, was performed on the calibrated severity of autism. Age was dropped from this model based on collinearity (a strong relationship of Mullen visual reception). When age was dropped from the linear regression standard gross motor skills as based on the MSEL were not a significant predicted of calibrated severity of autism. This preliminary analysis informed ANCOVA which included standardized gross motor scores, non-verbal problem solving, gender and ethnicity. There were no significant interactions. Calibrated severity is based on a 10 point metric, validated based on standardized scores from children with ASD, PDD-NOS and Non-ASD, therefore including participants with PDD-NOS and Non-ASD is important so that participants with lower calibrated severity scores (fewer autism symptoms) are included in this study. ANCOVA using the standard gross motor skills based on the MSEL found significant effects of diagnosis on the calibrated severity of autism ($p < 0.001$) but not gross motor skills (Table 2.5). Since standard gross motor T scores (based on the MSEL) were not well distributed a visual binning analysis was conducted, distributing the data into the categories of low, medium and high motor scores (based on MSEL gross motor standard scores). ANCOVA performed on the categorical gross motor skills based on visual binning revealed that gross motor skills were a significant predictor of calibrated severity of autism (Table 2.6), with all other variables held constant.

Discussion

The fine and gross motor skills in young children with autism predicted calibrated autism severity. Children with worse fine and gross motor deficits received a higher calibrated autism severity score. This study indicates a relationship between the motor skill deficits of children with autism and social communicative deficits, as indicated through calibrated autism severity. In addition, descriptive analyses of motor skills indicated clear motor deficits were evident in this young group of children (see Table 2.1 and 2.2).

In autism literature, motor skills have started to receive more attention (Chawarska, et al., 2007; Lloyd, et al., 2011; Sutera, et al., 2007). The fine and gross motor deficits in this study are concerning especially given the young age range of the children (14- 33 months). Early motor skill deficits have been indicated in early diagnosis (Teittelbaum, et al., 1998), positive prognosis (outcome) (Sutera, et al., 2007) and often motor skills are used as inclusion criteria for early social communicative interventions (such as the ability to walk). In autism literature the motor skills of children are discussed, but beyond acknowledging occupational and physical therapy, inventions focused on improving motor skills for these young children are relatively underexplored (Provost, Heimerl, et al., 2007; Provost, Lopez, et al., 2007). On the contrary, early intervention focused on social communication skills is a priority in autism research (NRC, 2001). Although it is not surprising that early intervention is focused on social communicative skills, it is possible that motor skills are impacting social communicative success (Sutera, et al., 2007). In this large diagnostic sample of children with autism and non-autism fine and gross motor skills already show a relationship to the social communicative domain, based on the predictive validity of motor skills in calibrated autism severity (see Tables 2.4 & 2.6).

The recent publication of the calibrated autism severity scores adds an interesting diagnostic tool for research in autism spectrum disorders (Gotham, et al., 2009). Calibrated severity is mapped based on ADOS raw scores, a diagnostic tool which characterizes the core deficits of autism based on behaviors in the social communicative domain and repetitive and restricted interests. Of note, the ADOS is the "gold standard" in autism diagnosis (Lord, 2000; Lord, Rutter, DiLavore, & Risi, 1999; Matson & Sipes, 2010). The calibrated severity score algorithms were not privy to motor skill data during calculation. This large well-defined diagnostic sample was the first of its kind to use motor skills as a predictor in social communicative deficits based on calibrated severity scores. The restricted age range of the sample sheds light on how motor skills might impact social communicative skills at such a young age (fine motor skills deficits and calibrated severity scores). The fine and gross motor skills as indicated through the MSEL were a significant predictor of calibrated severity and therefore predictive of the social communicative domain. Beyond the immediate relationship of motor skills and calibrated severity, age equivalent motor skills revealed 6-9 month deficits in this young group of children (see Tables 2.1 & 2.2).

Evidence-based research supports early intervention as one of the most widely accepted and best modes of treatment for young children with autism (Dawson, et al., 2010; Kasari, et al., 2006; Kasari, et al., 2005; Kasari, et al., 2010; Kasari, et al., 2008; Wong & Kwan, 2010). It has been recognized as a significant factor in positive prognosis for children with autism and establishing early intervention "sooner rather than later" has been accepted as a necessity (Dawson, et al., 2010; NRC, 2001; Sutera, et al., 2007). Amongst researchers and clinicians consensus exists on the necessity of early intervention, yet there is less agreement on content (Kasari, et al., 2005). Clearly the social communicative deficits in children with autism are of the utmost concern, and an essential target in treatment. Nevertheless research has established significant deficits in motor skills, even at an early age (Lloyd, et al., 2011; Provost, Heimerl, et al., 2007; Provost, Lopez, et al., 2007). Motor deficits are beginning to be recognized as a phenotypic characteristic of autism, potential diagnostic marker of autism and influential in autism prognosis (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Sutera, et al., 2007; Teittelbaum, et al., 1998). While only beginning to receive attention, the influence of this line of research may be significant in early intervention.

Early intervention is a priority in autism research, yet challenges exist in conducting this type of research. The scientific strength of randomized control trials is important for research and evidence-based practice, but there is an elevated drop rate of control participants from research. Once aligned with the control group families often drop out of the study and seek treatment elsewhere (Lord et al., 2005). Parents have a hard time understanding the relevance of the research, which should not to be mistaken with the relevance of early intervention (Lord, et al., 2005). Therefore, finding modes of treatment that are meaningful, accessible and 'parent-friendly' is important in autism research (Meadan, Ostrosky, Zaghlawan, & Yu, 2009). Motor skills, a functional and tangible behavior, may be one avenue of intervention to help parents implement intervention success at home. Although this is an initial relationship, the use of adapted equipment and basic motor skill programs have been successful in populations of young children, aimed at improving motor skills (Goodway & Branta, 2003).

Motor skills are predictive of calibrated severity and this relationship may impact intervention content. In addition to teaching social communicative skills such as eye contacting, requesting and play skills, teaching discrete motor skills may be important too and could be targeted in early intervention. Play-based activities are commonly used in early intervention and although the activities are targeted at improving social communication skills inefficient motor skills may be a hindering factor in the children's ability to participate in some of these activities.

One research area that has established connections between motor deficits and social communication skills is neurodevelopment (Fournier, et al., 2010). Neurodevelopment research in autism suggests that there are neurobiological underpinnings for the motor deficits presented in individuals with autism (Fournier, et al., 2010). A recent meta-analysis of motor coordination in ASD argues that the motor deficits should be considered a core feature of autism spectrum disorder, alongside social and communicative deficits and repetitive and restricted behaviors. This same study argued that intervention should seriously take these deficits into consideration (Fournier, et al., 2010). Other neurodevelopment researchers have made similar suggestions (Ben-Sasson et al., 2009). FMRI studies have acknowledged that neural systems responsible for the procedural acquisition of motor skills are also critical in language and social development (Mostofsky et al., 2009).

Aside from social communicative and motor relationships in neurodevelopmental research, behavior-driven research has suggested that motor skills could hinder success in early intervention (Sutera, et al., 2007). Children who started this early intervention with better motor skills finished with a more positive outcome (Sutera, et al., 2007). In typically developed children the relationship of motor development and movement skills have been made in both language production and active play (Kasari, et al., 2006; Kasari, et al., 2005; Kasari, et al., 2008; Luyster, Lopez, & Lord, 2007; Luyster & Lord, 2009). Better motor skills allow children to explore their environment, and exploration gives opportunity to participation and therefore practice of other social communication skills, such as play with other children.

Understanding how motor skills relate to the calibrated severity of children with autism is a step closer towards understanding how motor skills impact social communicative success. The calibrated severity metric represents autism severity as indicated through social communicative and repetitive or restricted behaviors, all of which are core characteristics of autism (Gotham, et al., 2009). In this study, fine and gross motor skill deficits based on the MSEL were related to higher levels of calibrated autism severity, which ultimately represents stronger deficits in the social communicative domain. Therefore, it seems likely that interventions focused on improving motor skills may ultimately lead to improvements in the social communicative domain.

Without doubt social communicative deficits are evident and prominent in young children with autism, but this study shows a relationship between these core deficits and motor skills. Motor skills act as foundational skills for active play and without proficient or even adequate motor skills children may be further disadvantaged towards learning and practicing new social communicative skills- and this has implications for early intervention success.

Future studies need to address this relationship further. Although studies have indicated that calibrated severity is relatively stable, we see positive developmental trajectories in very young children with autism spectrum disorder (Dawson, et al., 2010; Ozonoff et al., 2010; Ozonoff et al., 2008; Yirmiya & Ozonoff, 2007). Implementing successful interventions targeted at improving basic motor skills may further assist children in improvements of calibrated severity and improvements of social communicative skills.

Conclusion

Establishing efficacious early intervention programs is a priority in autism research (Kasari, et al., 2005; Yirmiya & Ozonoff, 2007). Dawson et al. (2010) were the first group to conduct a well controlled randomized control trial of early intervention for toddlers with autism spectrum disorder. This novel study provided clear evidence that early intervention improves IQ, language, adaptive behavior and autism diagnosis. However, early intervention content is still an ongoing area of study. The results of this study suggest that there is more to focus on and new avenues to explore including the importance of including motor skill learning in early intervention programs.

Fine and gross motor skills are predictive of severity, yet with such a young group of children with autism, there is opportunity for autism severity to improve- albeit with the appropriate intervention techniques. In addition to the health-related benefits of improved motor skills, the calibrated severity and social communicative skills of such young children with autism may also benefit.

References

American Phychiatric Association (APA). (1994). *Diagnostic and statistical manual for mental disorders, 4th Edition*, Washington, DC: American Psychiatric Association.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of Autism and Development Disorders, 39*(1).

Carter, A., Black, D., Tewani, S., Connolly, C., Kadlec, M., & Tager-Flusberg, H. (2007). Sex differences in toddlers with autism spectrum disorders. *Journal of Autism and Developmental Disabilities, 37*(1), 86-97.

Chawarska, K., Paul, R., Klin, A., Hannigen, S., Dichtel, L., & Volkmar, F. (2007). Parental recognition of developmental problems in toddlers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(1), 62-72.

Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., et al. (2010). Randomized, controlled trial of an intervention for infants with autism: The Early Start Denver Model. *Pediatrics, 125*(1), 17-23.

DiLavore, P., Lord, C., & Rutter, M. (1995). Pre-linguistic autism diagnostic observation schedule. *Journal of Autism and Developmental Disabilities, 25*(4), 355-379.

Eikeseth, S. (2009). Outcome of comprehensive psycho-educational interventions for young children with autism. *Research in Developmental Disabilities, 30*, 158-178.

Esposito, G., & Venuti, P. (2008). Analysis of toddlers' gait after six months on independent walking to identify autism: A preliminary study. *Perceptual and Motor Skills, 106*, 259-269.

Fombonne, E. (2009). A Wrinkle in Time: From early signs to a diagnosis of autism. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(5), 463-464.

Fournier, K., Hass, C., Naik, S., Lodha, N., & Cauraugh, J. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Development Disorders, 40*(10), 1227-1240.

Goodway, J., & Branta, C. (2003). Influence of a motor skill intervention on fundamental motor skill development of disadvantaged preschool children *Research Quarterly for Exercise and Sport, 74*(1), 36-46.

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(5), 693-705.

Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for improved validity. *Journal of Autism and Development Disorders, 37*(4), 613- 627.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., et al. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine and Child Neurology, 51*(4), 311-316.

Hayward, D., Eikeseth, S., Gale, C., & Morgan, S. (2009). Assessing progress during treatment for young children with autism receiving intensive behavioural interventions. *Autism, 13*(6), 613-633.

Helt, M., Kelley, E., Kinsbourne, M., Pandey, J., Boorstein, H., Herbert, M., et al. (2008). Can children with autism recover? If so, how? *Neuropsychological Review, 18,* 339-366.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young children with autism: a randomized controlled intervention study. *Journal of Child Psychology and Psychiatry, 47*(6), 611-620.

Kasari, C., Freeman, S., Paperella, T., Wong, C., Kwon, S., & Gultrud, A. (2005). Early intervention of core deficits in autism. *Clinical Neuropsychiatry, 2*(6), 380-388.

Kasari, C., Gulsrud, A., Wong, C., Kwon, S., & Locke, J. (2010). Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *Journal of Autism and Development Disorders, 40*(9), 1045-1056.

Kasari, C., Paparella, T., Freeman, S., & Jahromi, L. (2008). Language outcome in autism: Randomized comparison of joint attention and play interventions. *Journal of consulting and clinical psychology, 75*(1), 125-137.

Landa, R., & Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders: A prospective study. *Journal of Child Psychology and Psychiatry, 47*(6), 629-638.

Leary, M., & Hill, D. (1996). Moving on: Autism and movement disturbance. *Mental Retardation, 34*(1), 39-53.

Levinson, L. J., & Reid, G. (1993). The effects of exercise intensity on the stereotypic behaviors of individuals with autism. *Adapted Physical Activity Quarterly, 10*(3), 255-268.

Lloyd, M., MacDonald, M., & Lord, C. (2011). The motor skills of toddlers with autism spectrum disorders. *Autism*, 1-18.

Lord, C. (2000). The Autism Diagnostic Observation Schedule- Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3).

Lord, C., Rutter, M., DiLavore, P., & Risi, S. (1999). *Autism diagnostic observation schedule: Manual.* Los Angeles: Western Pyschological Services.

Lord, C., Wagner, A., Rogers, S., Szatmari, P., Aman, M., Charman, T., et al. (2005). Challenges in evaluating psychosocial interventions for autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 35*(6), 695-708.

Lovaas, O. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychiatry, 55*(1), 3-9.

Luyster, R., Gotham, K., Guthrie, W., Coffing, M., Petrak, R., Pierce, K., et al. (2009). The Autism Diagnostic Observational Schedule- Toddler module: A new module of a standardized diagnostic measure of autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*, 1305-1320.

Luyster, R., Lopez, K., & Lord, C. (2007). Characterizing communicative development in children referred for autism spectrum disorders using the MacArthur-

Bates Communicative Inventory (CDI). *Journal of Child Language, 34*(3), 623-654.

Luyster, R., & Lord, C. (2009). Word learning in children with autism spectrum disorders. *Developmental Psychology, 45*(6), 1774-1786.

Makrygianni, M., & Reed, P. (2010). A meta-analytic review of the effectiveness of behavioural early intervention programs for children with autistic spectrum disorder. *Research in Autism Spectrum Disorders, 4*(4), 577-593.

Matson, J., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 418-425.

Matson, J., & Sipes, M. (2010). Methods of early diagnosis and tracking for autism and Pervasive Developmental Disorder Not Othewise Specified (PDDNOS). *Journal of Developmental and Physical Disabilities, 22*, 343-358.

Matson, J., & Wilkins, J. (2009). Psychometric testing methods for children's social skills. *Research in Developmental Disabilities, 30*(2), 249-274.

Meadan, H., Ostrosky, M., Zaghlawan, H., & Yu, S. (2009). Promoting the social and communicative behavior of young children with autism spectrum disorders: A review of parent-implemented intervention studies. *Topics in early childhood special education, 29*(2), 90-104.

Mostofsky, S., Powell, S., Simmonds, D., Goldberg, M., Caffo, B., & Pekar, J. (2009). Decreased connectivity and cerebellar activity in autism during motor task performance. *Brain, 132*(9), 2413-2425.

Mullen, E. (1995). *Mullen scales of early learning (AGS ed.)*. Circle Pines: MN: American Guidance Services.

National Research Council (NRC). (2001).

Ozonoff, S., Iosif, A., Baguio, F., Cook, I. C., Hill, M. M., Hutman, T., et al. (2010). A prospective study of the emergence of early behavioral signs of autism. *Journal of the American Academy of Child and Adolescent Psychiatry, 49*(3).

Ozonoff, S., Young, G. S., Goldring, S., Greiss-Hess, L., Herrera, A. M., Steele, J., et al. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorders, 38,* 644-656.

Provost, B., Heimerl, S., & Lopez, B. R. (2007). Levels of gross and fine motor development in young children with autism spectrum disorder. *Physical & Occupational Therapy in Pediatrics, 27*(3).

Provost, B., Lopez, B. R., & Heimerl, S. (2007). A comparison in motor delays in young children: Autism spectrum disorder, developmental delay, and developmental concerns. *Journal of Autism and Developmental Disorders, 37,* 321-328.

Reid, G., O'Connor, J., & Lloyd, M. (2003). The Autism Spectrum Disorders. *Palaestra, 19*(2).

Rogers, S., Hall, T., Osaki, D., Reaven, J., & Herbison, J. (2000). A comprehensive, integrated, educational, approach to young children with autism and their families *Preschool education programs for children with autism (2nd ed).* Austin, TX: Pro-Ed.

Staples, K., & Reid, G. (2009). Fundamental movement skills and autism spectrum disorders.

Sutera, S., Pandey, J., Esser, E. L., & Rosenthal, M. A. (2007). Predictors of optimal outcome in toddlers diagnosed with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 98-107.

Teittelbaum, P., Teittelbaum, O., Nye, J., Fryman, J., & Maurer, R. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Psychology, 95*, 13982-13987.

Vernazza-Martin, S., Martin, N., Vernazza, A., Lepellec-Muller, A., Rufo, M., Massion, J., et al. (2005). Goal directed locomotion and balance control in autistic children. *Journal of Autism and Developmental Disorders, 35*(1), 91-102.

Wong, V. C. N., & Kwan, Q. K. (2010). Randomized controlled trial for early intervention for autism: A pilot study of the autism 1-2-3 Project. *Journal of Autism and Developmental Disorders, 40*, 677-688.

Yirmiya, N., & Ozonoff, S. (2007). The very early autism phenotype. *Journal of Autism and Developmental Disabilities, 37*(1), 1-11.

Table Captions.

Table 2.1. Descriptive characteristics of the participants.

Table 2.2. Average motor skill difference variable based on the difference between the motor age equivalent score and the child's chronological age.

Table 2.3. Analysis of covariance (ANCOVA) for Fine Motor skills (standard scores) on Calibrated Severity of Autism.

Table 2.4. Analysis of covariance (ANCOVA) for categorical Fine Motor skills on Calibrated Severity of Autism.

Table 2.5. Analysis of covariance (ANCOVA) for Gross Motor skills (standard) on Calibrated Severity of Autism.

Table 2.6. Analysis of covariance (ANCOVA) for categorical Gross Motor skills on Calibrated Severity of Autism.

Variable	Mean/ Frequency	N= 159
Age (months)	27.63 (4.6)*	
Gender	125M, 34F	
Race/ Ethnicity	108 Caucasian, 48 African American, 1 Native American, 1 Biracial, 1 Unspecified	
Maternal Education	23 Graduate/ Professional, 42 College, 44 Some College, 28 High School Diploma, 2 Some High School, 20 Unspecified	
Autism Diagnostic Classification	110 ASD, 26 PDD-NOS, 23 Non-ASD	
Age Equivalent Gross Motor Subtest	21.23 (6.1)	
Age Equivalent Fine Motor Subtest	18.11 (5.7)	
Age Equivalent Visual Reception Subtest	19.12 (6.4)	
Age Equivalent Receptive Language Subtest	9.67 (7.0)	
Age Equivalent Expressive Language Subtest	10.35 (5.8)	
Vineland Fine Motor Age Equivalent Subtest	17.53 (4.9)	
Vineland Gross Motor Age Equivalent Subtest	19.54 (5.2)	
Vineland Overall Motor Age Equivalent Subtest	18.69 (5.0)	
Vineland Standard Motor Score	76.59 (13.0)	
Ratio Verbal IQ	37.2 (22.6)	
Ratio Non-Verbal IQ	68.7 (21.4)	

Table 2.1. Descriptive characteristics of the participants *Mean (standard deviation)

Variable	ASD	PDD-NOS	non-ASD	Group (combined)	N= 159
Gross motor difference variable (months)	7.2 (5.5)*	7.0(6.0)	5.6(5.1)	6.9(5.5)	
Fine motor difference variable (months)	10.4(6.1)	8.1(6.5)	7.0(6.2)	9.5(6.3)	

Table 2.2. Average motor skill difference variable based on the difference between the motor age equivalent score and the child's chronological age.

*Mean (standard deviation)

	B	Std. Error	t	p
Intercept	2.97	.589	5.04	<0.001
Demographics				
Gender= M	.355	.300	1.18	.238
Gender= F	0			
Ethnicity= C	.186	.244	.762	.448
Ethnicity= Other	0			
Diagnosis				
Autism	6.36	.336	18.9	<0.001
PDD-NOS	3.23	.397	8.13	<0.001
Non-Autism	0			
Measures				
Non-verbal problem solving	.013	.022	.577	.565
Fine motor skills (standard)	-.039	.012	-3.24	≤0.001

Full Model

Table 2.3. Analysis of covariance (ANCOVA) for Fine Motor skills (standard scores) on Calibrated Severity of Autism

	B	Std. Error	t	p
Intercept	1.33	.673	1.97	≤0.05
Demographics				
Gender= M	.386	.300	1.28	.202
Gender= F	0			
Ethnicity= C	.163	.245	.666	.507
Ethnicity= Other	0			
Diagnosis				
Autism	6.36	.338	18.9	<0.001
PDD-NOS	3.15	.398	7.90	<0.001
Non-Autism	0			
Measures				
Non-verbal problem solving	.013	.022	.485	.629
Fine motor skills-Low	.945	.284	3.32	≤0.001
Fine motor skills-Medium	.460	.337	1.36	.175
Fine motor skills-High	0			

Full Model

Table 2.4. Analysis of covariance (ANCOVA) for categorical Fine Motor skills on Calibrated Severity of Autism

	B	Std. Error	t	p
Intercept	2.46	.538	4.57	<0.001
Demographics				
Gender= M	.239	.286	.836	.404
Gender= F	0			
Ethnicity= C	.027	.243	.113	.910
Ethnicity= Other	0			
Diagnosis				
Autism	6.49	.344	18.84	<0.001
PDD-NOS	3.14	.406	7.74	<0.001
Non-Autism	0			
Measures				
Non-verbal problem solving	-.027	.022	-1.22	.222
Gross motor skills (standard)	.008	.011	.719	.473

Table 2.5. Analysis of covariance (ANCOVA) for Gross Motor skills (standard) on Calibrated Severity of Autism

	B	Std. Error	t	p
Intercept	.607	.777	.780	.436
Demographics				
Gender= M	.109	.270	.405	.686
Gender= F	0			
Ethnicity= C	.261	.230	1.14	.257
Ethnicity= Other	0			
Diagnosis				
Autism	6.38	.322	19.81	<0.001
PDD-NOS	3.19	.380	8.39	<0.001
Non-Autism	0			
Measures				
Non-verbal problem solving	-.067	.022	-3.05	<0.01
Gross motor skills- Low	-.928	.321	-2.89	<0.01
Gross motor skills- Medium	.010	.314	.032	.974
Gross motor skill- High	0			

Table 2.6. Analysis of covariance (ANCOVA) for categorical Gross Motor skills on Calibrated Severity of Autism

Chapter 3

The relationship of motor skills and the adaptive social and communicative behavior in young children with autism.

Introduction

Autism spectrum disorder (ASD or autism) is a pervasive developmental disorder characterized by deficits in social skills, communication and repetitive or restricted interests (American Psychiatric Association [APA], 1994). Recent prevalence statistics suggest that 1 in every 110 children are diagnosed with autism (CDC, 2011; Matson & Kozlowski, 2011). Diagnostic measures have been standardized and can identify children with autism at a very young age (Gotham, Risi, Pickles, & Lord, 2007; Lord, 2000; Luyster et al., 2009b; NRC, 2001). The continuous rise in diagnosis has been the focus of controversy and a highly debated topic in the field of autism (Matson & Kozlowski, 2011). The controversy has been focused on why autism prevalence has increased so rapidly and drastically in recent years. Embedded in the controversial discussion is the role of genetics, other associated disabilities, diagnostic tools, vaccines and environment (Matson & Kozlowski, 2011; Matson & Sipes, 2010). Although a plethora of theories exist, there is no known specific cause to account for the rise in diagnosis (Matson & Kozlowski, 2011). This makes autism one of the most frequent childhood neurodevelopmental disorders (Fombonne, 2009).

Global screening for autism has been recommended by the American Academy of Pediatrics (AAP) for all young children twice in early childhood, at 18 months and 24 months (AAP, 2007). National campaigns have been initiated by major research-driven autism authorities to educate parents on the early signs of autism spectrum disorder (Autism Speaks, 2010; CDC, 2011). Unfortunately, the rising prevalence poses difficulty for service providers in adhering to the concurrent increase in early intervention service needs for this group of young children (Downs & Downs, 2010; Wise, Little, Holliman, Wise, & Wang, 2010). Best practice recommendations for early intervention include: immediate enrollment when children are suspected of having ASD, a minimum of 25 hours of focused intervention with an adequate teacher (weekly) and the opportunity to interact with age-matched typically developed peers (NRC, 2001). Based on the feedback from State early intervention service providers, children suspected of having autism typically experience 6-month service waitlists and markedly less than the minimum of 25 hours of recommended service hours.

In addition to the hallmark characteristic of autism, social communicative deficits, children with autism also display deficits in motor skills (Lloyd, MacDonald, & Lord, 2011; Matson, Mahan, Fodstad, Hess, & Neal, 2010; Provost, Heimerl, & Lopez, 2007; Provost, Lopez, & Heimerl, 2007; Teittelbaum, Teittelbaum, Nye, Fryman, & Maurer, 1998; Yirmiya & Ozonoff, 2007). In some of the original clinical descriptions of what is now called autism, Asperger attached considerable weight to motor clumsiness (Frith, 1991). Why children with autism display deficits in motor skills is a question of interest for many researchers in the field. How autism manifests and the neural system involvement is an ongoing area of study (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Mostofsky, Burgess, & Gidley Larson, 2007; Mostofsky et al., 2009).

Unfortunately motor deficits appear early in life for many young children with autism, and become prominent around 14- 24 months of age (Chawarska et al., 2007). Currently, the use of motor performance in autism diagnosis is embedded in gestures, stereotypies and imitation (Lord, 2000; Luyster et al., 2009a). However empirical research has suggested that motor skill deficits may be one of the earliest detectable signs of autism and a cardinal feature of the disability (Fournier, et al., 2010; Sutera, Pandey, Esser, & Rosenthal, 2007; Teittelbaum, et al., 1998).

In the youngest children with autism, delayed infant motor milestones have been reported (Chawarska, et al., 2007; Landa & Garrett-Mayer, 2006; Lloyd, et al., 2011; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). Parents have noticed motor delays early in development and delayed motor milestones (especially walking) have acted as an initial developmental concern to parents, who later received an autism diagnosis for their child (Chawarska, et al., 2007). Retrospective research has confirmed that early motor delays are present in children with autism at a young age (Lloyd, et al., 2011; Teitelbaum, et al., 1998). Prominent motor deficits start to appear between the ages of 14- 24 months of age (Chawarska, et al., 2007; Landa & Garrett-Mayer, 2006). When children at high-risk for autism (children who had a sibling with autism), were studied prospectively three groups emerged for comparison, children with language delay, autism and typical development (Landa & Garrett-Mayer, 2006). Deficits in fine motor skills were evident in children with autism at 6 months of age and significantly worsened fine and gross motor skills were evident at 14 and 24 months of age (Landa &

Garrett-Mayer, 2006). This prospective study suggested early motor deficits as a potential diagnostic distinction between children with autism and children with other developmental delays (language delay) (Landa & Garrett-Mayer, 2006).

Retrospective video analysis of young children with autism, indicated that motor delays early in development act as some of the first signs of developmental concern (Teitelbaum, et al., 1998). Through video analysis Teitelbaum, et al. (1998) found oral motor deficits as well as delays in motor milestones such as lying, righting, sitting, crawling and walking present in young children with autism at a young age. When 75 toddlers with autism and pervasive developmental disorder- not otherwise specified (PDD-NOS) were studied from age 2-4 years, early motor delays as well as social communicative delays were helpful in earlier recognition of autism (Chawarska, et al., 2007). A large cross-sectional study of young children with autism (n= 172, aged 18- 36 months) found that fine and gross motor deficits became worse going from toddlers to preschool (Lloyd, et al., 2011).

Other motor deficits have been found in gait and postural control. Children with autism (aged 4- 6 years) demonstrated a short step length and irregular body oscillations during locomotion consistent with a less stable and more variable posture compared to a control group without a disability (Vernazza-Martin et al., 2005). Young children with autism (less than 2 years) displayed similar gait and postural control deficits (Esposito & Venuti, 2008). At 20 months of age children with autism showed deficits in gait parameters which included performing abnormal heel-to-toe patterns, odd arm posturing and generally higher frequencies of anomalies in movement including waddle walking (Esposito & Venuti, 2008).

Motor planning deficits were evident when children with autism could not translate motor intention into a global motor action, but rather treated each motor task involved in an overall action as an independent task (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). Similarly, Vernazza-Martin et al. (2005) found that young children with autism had difficulty defining the goal of the motor action consistent with motor planning deficits. Even when the task was adapted in a highly motivating fashion, children appeared to understand the motor instruction, evident in their purposeful action of moving toward the object, but the final motor goal could not be completed, indicating shortfalls in motor planning (Vernazza-Martin, et al., 2005). These children were able to perform simple motor tasks but unable to chain multiple motor tasks together into a more complex motor action, consistent with motor planning deficits.

These descriptive studies have clearly demonstrated that deficits in motor skills exist in children with autism at a young age and have even gone so far as to suggest early motor deficits as a preliminary diagnostic marker of autism spectrum disorder and a cardinal characteristic of the disorder (Fournier, et al., 2010; Matson, et al., 2010; Teittelbaum, et al., 1998). Deficits have been found in gait, postural control, motor planning, locomotor skills, object-control skills and infant motor milestones (Berkeley, Zittel, Pitney, & Nichols, 2001; Rinehart et al., 2006; Staples & Reid, 2009; Sutera, et al., 2007; Teittelbaum, et al., 1998; Vernazza-Martin, et al., 2005).

Even though motor skill deficits are present in young children with autism, the primary focus of early intervention is based on social communication deficits and improving these skills (Dawson et al., 2010; Kasari, Freeman, & Paparella, 2006; Kasari et al., 2005; Rogers, 2000; Rogers, Hall, Osaki, Reaven, & Herbison, 2000). Emperical research suggests motor deficits are prominent and pervasive across time and age, however very little has been discussed in terms of how motor skill deficits interact with the core-characteristics of autism, deficits in social communication skills (Berkeley, et al., 2001; Fournier, et al., 2010; Landa & Garrett-Mayer, 2006; Lloyd, et al., 2011; Staples & Reid, 2009).

Early intervention for young children with autism is consistently recommended as a necessity (Dawson, et al., 2010; Kasari, et al., 2005; Kelley, Naigles, & Fein, 2010; NRC, 2001). The focus of early intervention is social communicative, this includes improving skills such as imitation, joint attention and play (functional and symbolic play skills) (Kasari, et al., 2005). Randomized control trials have undoubtedly displayed that intensive early intervention significantly improves behavior in the social communicative domain as well as other aspects of autism symptomology (Dawson, et al., 2010; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Wong & Kwan, 2010). Early intervention has been successful at improving IQ, language, play skills, adaptive behavior and autism diagnosis (ie. moving from autism, to PDD-NOS) (Dawson, et al., 2010; Kasari, et al., 2006; Kasari, Paparella, Freeman, & Jahromi, 2008). Although there is widespread agreement on the necessity of early intervention, there is less consistent agreement on early intervention content (Kasari, et al., 2005).

The importance of social communication skills for young children with autism has been clearly been indicated (Dawson, et al., 2010; Helt et al., 2008; Kasari, et al., 2005; Kasari, et al., 2010; Kasari, et al., 2008; Kelley, et al., 2010; Wong & Kwan, 2010). How motor skills impact social communicative skills and on the other hand, how social communicative skills may impact the motor skills of young children with autism is an area of study that is relatively underexplored. It is possible that the motor skills of young children with autism are affecting social communication skills. The hypothesis for this study is that stronger motor skills, both fine and gross motor skills, provide more opportunity for social communicative success.

The purpose of this study is to test the relationship of fine and gross motor skills on the adaptive behavior composite, daily living skills, social and communicative skills of children with ASD, PDD-NOS and non-ASD.

Method

Participants. The Medical Institutional Review Board at the University of Michigan approved all methods and procedures for this study. Young children with ASD, PDD-NOS and non-ASD between the ages of 12- 60 months were recruited from early intervention studies and clinical referrals to the University of Michigan Autism and Communicative Disorders Center (UMACC), an autism clinic in Chicago and a university autism clinic in North Carolina. Generally, children were recruited through autism support groups, study flyers and clinical referrals from pediatricians and teachers were informed of the study during clinical visits.

All participants (n=233) in this study were children between the ages of 14- 49 months (mean age= 30.36 months) with a confirmatory diagnosis of autism (ASD), pervasive developmental disorder- not otherwise specified (PDD-NOS) or non-ASD (non-autism developmentally delayed children).

Measurements

Child Diagnostic Measures. All participants were administered the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 1999) or its precursor, the Pre-Linguistic Autism Diagnostic Observation Schedule (PL-ADOS) (DiLavore, Lord, & Rutter, 1995), in order to acquire diagnostic information through direct observation of the children by a trained clinician. The participants at the Michigan center were administered the Toddler module of the ADOS (Luyster, et al., 2009a). Diagnosis was determined by standardized algorithms established for the Autism Diagnostic Observation Schedule (Gotham, Pickles, & Lord, 2009; Lord, 2000). The children's parents were also frequently administered the Autism Diagnostic Interview-Revised to confirm diagnosis (ADI-R; Rutter et al., 2001). A clinical psychologist or a trainee who had completed research training and met standard requirements for research reliability administered the ADOS (Lord, et al., 1999).

Each member of the research clinical teams, at all centers, established inter-rater reliability exceeding 90% exact agreement (kappa>0.70) for all items on the ADI-R and 80% exact agreement (kappa>0.60) on codes for the PL-ADOS, ADOS, and Toddler module for three consecutive administrations before the studies began. Reliability was maintained over time through consensus coding, approximately every sixth administration with a second rater.

Developmental Level Measurement. The Mullen Scales of Early Learning (MSEL) (Mullen, 1995) was used to assess cognitive development. This test of development provides reliable and valid information for children from birth to 68 months of age. The subscales on the MSEL are organized into 5 domains: gross motor, fine motor, visual reception (nonverbal problem solving), receptive language, and expressive language. An early learning composite score is derived from the fine motor, visual reception, receptive language and expressive language scales.

The Vineland Adaptive Behavior Scales (VABS) (Sparrow, Cicchetti, & Balla, 2005) were used to assess adaptive skills. The VABS is a standardized parent-report measure of everyday adaptive functioning and yields domain scores in the areas of communication, daily living skills, social skills, and motor development (fine motor and gross motor). This assessment was administered by interview or over the phone, to the parent or primary caregiver of the participant.

Motor Skill Measurement. The gross motor scale of the MSEL was used to assess gross motor skills (Mullen, 1995). This scale was administered in a clinical setting with other developmental and diagnostic measures at baseline. Age equivalent scores were used for analysis because standardized scores are not provided for children beyond 33 months of age (even though most children with ASD do not meet the ceiling requirements of this subscale). The gross and fine motor subtests of the MSEL were used to assess the gross and fine motor skills of the children with ASD based on age equivalent scores.

Data Reduction. All examiners strictly adhered to the standardized procedures outlined in each respective test manual. As indicated in the measurement description, research reliability and inter-rater reliability was established for the ADOS. Autism cut-off was based on new revised standardized algorithms (Gotham, et al., 2007). These algorithms included scores based on social communication, repetitive and restricted interests and stereotyped behaviors. All assessments were conducted by experienced administrators who were familiar in working with young children with autism. In addition to the ADOS, the MSEL was administered to all participants. Descriptive characteristics of the sample also include an age difference score- the age difference score was calculated based on the chronological age of the participant and the child's as based on MSEL norms (Mullen, 1995).

Data Analysis. Data analysis consisted of a regression analysis to test the relationship of fine and gross motor skills on the adaptive behavior composite, daily living skills, social and communicative skills of children with ASD, non-ASD and PDD-NOS. Adaptive behavior, daily living skills, social and communicative skills were indicated through the standardized scales of the Vineland Adaptive Behavior Scales (VABS) (Sparrow, et al., 2005). A preliminary analysis, tested fine and gross motor skills on each dependent variable holding constant age and non-verbal problem solving and informed analysis (a linear regression was conducted separately for both fine and gross motor skills). A final analysis consisted of analysis of covariance (ANCOVA) designed to hold important variables constant- including age, non-verbal problem solving, gender, ethnicity and autism diagnosis (ASD, PDD-NOS and non-ASD).

Results

A total of 233 children with a confirmatory diagnosis of ASD (n= 172), PDD-NOS (n= 22) and non-ASD (n= 39) were included in this study (mean age= 30.36 months). Descriptive characteristics of the sample can be found in Table 3.1. The average fine and gross motor deficits in months are reported in Table 3.2.

A correlation analysis revealed strong correlations between all dependent variables (Table 3.3). Initial analyses were conducted on the adaptive behavior composite, comprised of all subscales, and then separate analyses were conducted for each scale of interest.

Influence of Fine Motor Skills on Adaptive Behavior Composite

An initial linear regression analysis tested the moderation of fine motor skills, age and visual receptive organization (non-verbal problem solving) on the adaptive behavior composite of young children with autism. In this initial linear regression, fine motor skills ($p < 0.001$), age ($p < 0.001$) and visual receptive organization ($p < 0.05$) were significant predictors of the adapted behavior composite. The initial linear regression informed analysis of covariance (ANCOVA) fitting non-verbal problem solving, age, fine motor skills, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no interactions. The final model showed fine motor skills ($p < 0.001$), diagnosis ($p < 0.001$) and age ($p < 0.001$) were significant predictors of the adaptive behavior composite holding all variables constant (see Table 3.4). This final model indicated that children with worse fine motor skills had lower adaptive behavior composite scores.

Influence of Gross Motor Skills on Adaptive Behavior Composite

An initial linear regression analysis tested the moderation of gross motor skills, age and visual receptive organization (non-verbal problem solving) on the adapted behavior composite of young children with autism. In this initial linear regression gross motor skills ($p < 0.001$), age ($p < 0.001$) and visual receptive organization ($p < 0.001$) were significant predictors of the adaptive behavior composite. The initial linear regression informed analysis of covariance (ANCOVA) fitting gross motor skills, non-verbal problem solving, age, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no interactions. The final model showed that gross motor skills ($p < 0.01$), ethnicity ($p < 0.001$), diagnosis ($p < 0.001$), age ($p < 0.001$) and visual receptive organization (non-verbal problem solving) ($p < 0.001$) were significant predictors of the adaptive behavior composite (see Table 3.6). Children with worse motor skills had lower adaptive behavior composite scores as indicated in the Vineland Adaptive Behavior Scale.

Influence of Fine Motor Skills on Daily Living Skills

An initial linear regression analysis tested the moderation of fine motor skills, age and visual receptive organization (non-verbal problem solving) on daily living skills. In this initial linear regression, fine motor skills ($p < 0.001$) and age ($p < 0.001$) were significant predictors. The preliminary analysis informed analysis of covariance (ANCOVA) fitting non-verbal problem solving, age, fine motor skills, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no significant interactions. The final model showed fine motor skills were a significant predictor of daily living skills when all other variables were held constant (see Table 3.4).

Influence of Gross Motor Skills on Daily Living Skills

An initial linear regression analysis tested the moderation of gross motor skills, age and visual receptive organization (non-verbal problem solving) on daily living skills. In this initial linear regression gross motor skills ($p < 0.01$), age ($p < 0.001$) and visual receptive organization ($p < 0.001$) were significant predictors of daily living skills. The initial linear regression informed analysis of covariance (ANCOVA) fitting non-verbal problem solving, age, gross motor skills, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no significant interactions. The final model showed that gross motor skills, ethnicity, diagnosis, age and visual receptive organization (non-verbal problem solving) were significant predictors of daily living skills (see Table

3.6). Gross motor skills were a significant predictor of daily living skills ($p < 0.01$), children with worse motor skills had a lower daily living skills as indicated in the Vineland Adaptive Behavior Scale.

Influence of Fine Motor Skills on Adapted Social Behavior

Preliminary analysis tested the ability of fine motor skills, age and visual receptive organization (non-verbal problem solving) to predict the adaptive social behavior of young children with autism. In this initial linear regression, fine motor skills ($p < 0.05$), age ($p < 0.001$) and visual receptive organization (non-verbal problem solving) ($p < 0.05$) were significant predictors of adapted social behavior. The preliminary analysis informed analysis of covariance (ANCOVA) fitting fine motor skills, age, visual receptive organization (non-verbal problem solving), gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD) to predict adaptive social behavior. There were no significant interactions in this model. The final model showed that fine motor skills, age, gender and diagnosis were significant predictors of adaptive social behavior (see Table 3.5). Significant predictors included age ($p < 0.001$) and fine motor skills ($p \leq 0.001$). This final model indicated that children with worse fine motor skills had lower social adaptive behavior.

Influence of Gross Motor Skills on Adaptive Social Behavior

Gross motor skills were not a significant predictor of standardized social adaptive behavior (as indicated on the Vineland Adaptive Behavior Scales) (see Table 3.7). An initial linear regression analysis tested the ability of gross motor skills, age and visual receptive organization (non-verbal problem solving) on the adapted social behavior of young children with autism. In this initial linear regression, age ($p < 0.001$), visual receptive organization ($p < 0.001$) and gross motor skills ($p < 0.05$) were significant predictors of adapted social behavior. The initial linear regression informed analysis of covariance (ANCOVA) fitting gross motor skills, non-verbal problem solving, age, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no significant interactions. The final model showed that gender, diagnosis, age and visual receptive organization (non-verbal problem solving) were significant predictors of adaptive social behavior (Table 3.7). Gender was a significant predictor of social adaptive behavior ($p < 0.01$), based on standard scores of the Vineland Adaptive Behavior Scales, males were more likely to receive a score 3.66 points below females. Diagnosis was also a significant predictor of adaptive social behavior ($p < 0.001$), when non-Autism was set to zero, children with autism scored on average 11.42 points behind non-autism and children with PDD-NOS were more likely to score 8.12 points behind non-autism. Other significant predictors included age ($p < 0.001$) and visual receptive organization ($p < 0.001$).

Influence of Fine Motor Skills on Adapted Communicative Behavior

An initial linear regression analysis tested the predictors fine motor skills, age and visual receptive organization (non-verbal problem solving) on the adaptive communicative behavior of young children with autism. In this initial linear regression, fine motor skills ($p < 0.01$), age ($p < 0.001$) and visual receptive organization ($p < 0.01$) were significant predictors of adapted communicative behavior. The initial linear regression informed analysis of covariance (ANCOVA) fitting fine motor skills, non-verbal problem solving, age, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no interactions. The final model showed that fine motor skills, gender, diagnosis, age and visual receptive organization (non-verbal problem solving) were significant predictors of adaptive communicative behavior holding all variables constant (see Table 3.5). Gender was a significant predictor of communicative adaptive behavior ($p < 0.01$), based on standard scores of the Vineland Adaptive Behavior Scales, males are more likely to receive a score 3.25 points below females. Diagnosis was also a significant predictor of adaptive communicative behavior ($p < 0.001$), when non-Autism was set to zero, children with autism scored 10.70 points behind non-autism and children with PDD-NOS were more likely to score 7.92 points behind non-autism. Other significant predictors included age ($p < 0.001$), visual receptive organization ($p < 0.05$) and fine motor skills ($p < 0.01$). This final model indicated that children with worse fine motor skills had lower communicative adaptive behavior.

Influence of Gross Motor Skills on Adaptive Communicative Behavior

The gross motor age equivalent scores on indicated on the Mullen were not a significant predictor of standardized communicative adaptive behavior (as indicated on the Vineland Adaptive Behavior Scales) (see Table 3.7). An initial linear regression analysis tested the moderation of gross motor skills, age and visual receptive organization (non-verbal problem solving) on the adapted communicative behavior of young children with autism. In this initial linear regression, age ($p < 0.001$) and visual receptive organization ($p < 0.001$) were significant predictors of adaptive communicative behavior. The initial linear regression informed analysis of covariance (ANCOVA) fitting non-verbal problem solving, age, gross motor skills, gender, ethnicity and autism diagnosis (ASD, PDD-NOS or non-ASD). There were no interactions. The final model showed that gender, diagnosis, age and visual receptive organization (non-verbal problem solving) were significant predictors of adaptive social behavior. Gross motor skills were not a significant predictor in this model. Gender was a significant predictor of communicative adaptive behavior ($p < 0.05$), based on standard scores of the Vineland Adaptive Behavior Scales, males are more likely to receive a score 3.13 points below females. Diagnosis was also a significant predictor of adaptive communicative behavior ($p < 0.001$), when non-Autism was set to zero, children with autism scores 10.65 points behind non-autism and children with PDD-NOS were more likely to score 7.62 points behind non-autism. Other significant predictors included age ($p < 0.001$) and visual receptive organization ($p < 0.001$).

Discussion

The purpose of this study was to investigate the relationship between fine and gross motor skills on the adaptive behavior composite, daily living skills, adaptive social and adaptive communicative behavior of children with ASD, PDD-NOS and non-ASD. Fine motor skills were predictive of behavior composite, daily living skills, adaptive social and adaptive communication based on the Vineland Adaptive Behavior Scales (2^{nd} edition) (Sparrow, et al., 2005). Gross motor skills were predictive of adaptive behavior composite and daily living skills.

These findings add important information about the relationship of motor and social communication skills in children with ASD. Motor skill deficits have been indicated in young children with ASD through retrospective and prospective research (Chawarska, et al., 2007; Lloyd, et al., 2011; Ozonoff et al., 2008; Teittelbaum, et al., 1998). Although motor skill deficits are persistent and pervasive in young children with ASD across time and age, early intervention is primarily focused on social communicative deficits (Kasari, et al., 2005; Lloyd, et al., 2011; Rogers, 2000; Trevarthen & Daniel, 2005; Zwaigenbaum et al., 2005).

Motor skill deficits range in nature and across tasks and it has been suggested that deficits in motor skill could in fact be hindering improvements in social communication skills (Lloyd, et al., 2011; Sutera, et al., 2007). Early motor deficits in young children with autism include delays in infant motor milestones, gait, postural control, fine and gross motor deficits and in older children with ASD basic movement skills needed for participation in physical education and playground activities (Chawarska, et al., 2007; Fabbri-Destro, et al., 2009; Matson, et al., 2010; Staples & Reid, 2009; Vernazza-Martin, et al., 2005).

Some studies have acknowledged a potential relationship in the social communicative and motor domains, however this suggested relationship has emerged from the data, and comparisons have not been planned (Landa & Garrett-Mayer, 2006; Ozonoff, et al., 2008; Sutera, et al., 2007). This study used the amount of motor deficit to map onto the social communication deficits and has indicated that a relationship of motor and social communicative deficits is evident in children with autism, even at a young age. Although the content of early intervention has focused on improving the social communication skills (Dawson, et al., 2010; Kasari, et al., 2006; Kasari, et al., 2010; Rogers et al., 2006), there is less agreement on specific content (Kasari, et al., 2005). Motor skills may be a missing component of current intervention programs and an additive piece to further improve motor skills and social communicative skills in young children with autism.

The results of this study indicate that fine motor skill deficits mapped onto behavior composite, daily living skills, adaptive social and adaptive communicative skills, while gross motor skill deficits mapped onto adaptive behavior composite and daily living skills. In previous studies, developmental level (IQ) and age have been important indicators for optimal early intervention outcome and therefore indicators of social success (Dawson, et al., 2010; Gotham, et al., 2009). Both of these factors have been taken into consideration in this study, and held constant in order to further exemplify the influence of fine and gross motor skills on social communicative behavior (non-verbal problem solving is a common stand-in for developmental level and a better indicator for children with autism given the amount of language delay common in autism). Fine and gross motor deficits are directly related to the primary outcome measures of early intervention for children with autism (based on social communicative improvement), and therefore could be potential factors in children's success.

With the best content for early intervention under investigation, and with early intervention on the forefront of ASD research, the importance of motor skills should also be considered (Dawson, et al., 2010; Kasari, et al., 2005; Matson & Kozlowski, 2011; Sutera, et al., 2007). The Denver model, an early intervention for young children with autism, might be the closest early intervention that successfully intertwines motor development, social communicative skills and social success; yet how proficient motor skills impact social success has not been measured (Rogers, 2000). In fact, many early interventions imply the use of games or activities to facilitate social learning and some of the activities require relatively proficient motor skills for success. For instance games like "chase", songs that require actions, climbing activities (like sliding or playing on equipment), as well as activities that include coloring or drawing are often important components of early intervention programs. Arguably, these activities may be more successful with more proficient motor skills. Unmistakably, the emphasis of the programs is social communicative, but it is possible that these two domains are already intertwined. Teaching age-appropriate motor skills might add to a practitioner's repertoire of intervention strategies aimed at improving social success (Lloyd, et al., 2011; Sutera, et al., 2007; Swiezy, 2008).

The results of this study are not meant to negate the importance of deficits in social communication prevalent in ASD. However the prevalence of motor deficits in young children with ASD needs to be considered in early intervention (Chawarska, et al., 2007; Lloyd, et al., 2011; Matson, et al., 2010; Ozonoff, et al., 2008; Teittelbaum, et al., 1998). Yet, the depth of motor deficits in children with ASD at a young age (age range 14- 36 months) causes concern (Lloyd, et al., 2011). The relationship of motor skills, with behavior, daily living skills, adaptive social and adaptive communicative skills suggests another avenue to further explore and possibly add to the social success of these young children.

The content of early intervention varies. Parent-driven early interventions are starting to gain recognition and have been successful (Vismara, Colombi, & Rogers, 2009). A diagnosis of autism can be overwhelming for families and it often requires a substantial change in familial schedules, programs and activities (Hall & Graff, 2011). Adhering to strict behavioral models of early intervention can be difficult, especially given the change in routine and schedules early intervention causes. Motor skills could be a relatively tangible skill for parents to conceptualize and possibly a set of skills to focus on when family or parental stress is elevated. Since motor skills are related to social communicative skills, this may help at improving social communicative skills too.

Adaptive social and communicative behavior is necessary for basic daily living skills. Deficits in motor skills are related to deficits of adaptive behavior composite, daily living skills, social and communicative skills independent of cognitive function (non-verbal problem solving). Since the improvement of social communication is critical in ASD in moving towards positive prognosis, and deficits in the same area are core features of ASD, the relationship of motor skills, a rather underexplored area, are important towards this endeavor. Social communication deficits are the single most defining feature of autism (Rogers, 2000). However, the results of this study show a direct relationship of the core characteristics of autism with motor skills.

This study is an initial step towards indicating the improvement of motor skills as a function of social communicative success. Although few, if any, interventions have focused on improving motor skills, motor skill deficits widen as children age, even in the early years (Lloyd, et al., 2011). In a description of the early autism phenotype social communicative deficits were evident in infant siblings, alongside motor deficits, such as delayed sitting and an unstable posture (Yirmiya & Ozonoff, 2007).

How to best implement motor skill improvement programs and how to combine early intervention to include motor skill improvement is an area of future research. However, programs such as those adapted through pre-school physical education and the use of adapted equipment, focused on motor skill improvement would be good starting points (Goodway & Branta, 2003). Children with ASD have unique characteristics which will be important to consider in motor skill programming. For example, using schedules and simple instruction consistent with visual and verbal prompts will be important. Behavior strategies sometimes including unique reward systems, simple tasks and the use of motivating adaptive equipment will be imperative. However, given the need for motor skill improvement and the relationship between motor skills and social communicative skills, this type of program might be a significant additive piece for young children diagnosed with autism in addition to more traditional early intervention programs.

Future directions

The necessity of early intervention for young children with ASD has clearly been indicated. However, a more concerning feature is agreement on program content. Direct comparisons of early interventions has just started (Kasari, et al., 2008). Retrospective comparisons of early intervention programs are difficult given different outcome measures used to suggest success (Lord et al., 2005; Matson & Sipes, 2010). Clearly, motor skills deficits have been indicated, and this study shows direct relationships between fine and gross motor skills for young children with autism. Next steps include motor skill interventions. Given the motor deficits in this group of children, group-based programs to improve these skills are imperative. If motor skill interventions are successful, how motor skill interventions improve social communication success may also provide important information. It is possible that the benefits of early motor skill intervention may yield similar improvements in outcome measures currently used to evaluate the success of social communicative early intervention programs.

Limitations

Limitations to this study include the retrospective nature of this work and the secondary data analysis. Age equivalent scores were used in order to standardize scores across ages, and increase the age range of the children in this study. More sensitive motor skills assessments need to be implemented to help in addressing this relationship.

Conclusion

Deficits in fine motor skills directly map onto the adaptive social, communicative, adaptive behavior composite and daily living skills of children with ASD, PDD-NOS and non-ASD. Deficits in gross motor skills directly map onto the adaptive behavior composite and daily living skills of children with ASD, PDD-NOS and non-ASD. These findings acknowledge that motor skills deficits are related to the core characteristics of ASD, deficits in the social and communicative domain. Furthermore, it has been suggested that motor skill deficits may be a cardinal feature of ASD and not secondary to deficits in the social communicative domain (Fournier, et al., 2010). Although more research need to be completed to acknowledge this statement, the results of this study further support that motor skills are influential, even when non-verbal problem solving was held constant. Not only are motor skills deficits present in children with ASD at a young age (Lloyd, et al., 2011), but the relationship of these deficits to the social communicative domain, may impact early intervention. Motor skills need to be considered and included in early intervention programming.

References

American Academy of Pediatrics (AAP). (2007).

Autism Speaks. (2010).

Berkeley, S. L., Zittel, L. L., Pitney, L. V., & Nichols, S. E. (2001). Locomotor and object control skills of children diagnosed with autism. *Adapted Physical Activity Quarterly, 18*(4), 405-416.

Center for Disease Control and Prevention (CDC). (2011).

Chawarska, K., Paul, R., Klin, A., Hannigen, S., Dichtel, L., & Volkmar, F. (2007). Parental recognition of developmental problems in toddlers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(1), 62-72.

Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., et al. (2010). Randomized, controlled trial of an intervention for infants with autism: The Early Start Denver Model. *Pediatrics, 125*(1), 17-23.

DiLavore, P. C., Lord, C., & Rutter, M. (1995). Pre-Linguistic Autism Diagnostic Observation Schedule (PLADOS). *Journal of Autism and Developmental Disorders, 25*(4), 355-379.

Downs, R. C., & Downs, A. (2010). Practices in early intervention for children with autism: a comparison with the national research council recommended practices. *Education and training in autism and developmental disabilities, 45*(1), 150-159.

Esposito, G., & Venuti, P. (2008). Analysis of toddlers' gait after six months on independent walking to identify autism: A preliminary study. *Perceptual and Motor Skills, 106*, 259-269.

Fabbri-Destro, M., Cattaneo, L., Boria, S., & Rizzolatti, G. (2009). Planning action in autism. *Experimental Brain Research, 192*(3), 521-525.

Fombonne, E. (2009). A Wrinkle in Time: From early signs to a diagnosis of autism. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(5), 463-464.

Fournier, K., Hass, C., Naik, S., Lodha, N., & Cauraugh, J. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Development Disorders, 40*(10), 1227-1240.

Frith, U. (1991). *Autism and Asperger syndrome.* Cambridge: Cambridge University Press.

Goodway, J., & Branta, C. (2003). Influence of a motor skill intervention on fundamental motor skill development of disadvantaged preschool children *Research Quarterly for Exercise and Sport, 74*(1), 36-46.

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(5), 693-705.

Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for improved validity. *Journal of Autism and Development Disorders, 37*(4), 613- 627.

Hall, H., & Graff, C. (2011). The relationships among adaptive behaviors of children with autism, family support, parenting stress & coping. *Issues in comprehensive pediatric nursing, 34*(1), 4-25.

Helt, M., Kelley, E., Kinsbourne, M., Pandey, J., Boorstein, H., Herbert, M., et al. (2008). Can children with autism recover? If so, how? *Neuropsychological Review, 18*, 339-366.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young children with autism: a randomized controlled intervention study. *Journal of Child Psychology and Psychiatry, 47*(6), 611-620.

Kasari, C., Freeman, S., Paperella, T., Wong, C., Kwon, S., & Gultrud, A. (2005). Early intervention of core deficits in autism. *Clinical Neuropsychiatry, 2*(6), 380-388.

Kasari, C., Gulsrud, A., Wong, C., Kwon, S., & Locke, J. (2010). Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *Journal of Autism and Development Disorders, 40*(9), 1045-1056.

Kasari, C., Paparella, T., Freeman, S., & Jahromi, L. (2008). Language outcome in autism: Randomized comparison of joint attention and play interventions. *Journal of consulting and clinical psychology, 75*(1), 125-137.

Kelley, E., Naigles, L., & Fein, D. (2010). An in-depth examination of optimal outcome children with a history of autism spectrum disorders. *Research in Autism Spectrum Disorders, 4*, 526-538.

Landa, R., & Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders: A prospective study. *Journal of Child Psychology and Psychiatry, 47*(6), 629-638.

Lloyd, M., MacDonald, M., & Lord, C. (2011). The motor skills of toddlers with autism spectrum disorders. *Autism*, 1-18.

Lord, C. (2000). The Autism Diagnostic Observation Schedule- Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3).

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (1999). *Autism Diagnostic Observation Schedule* Los Angeles: Western Psychological Services.

Lord, C., Wagner, A., Rogers, S., Szatmari, P., Aman, M., Charman, T., et al. (2005). Challenges in evaluating psychosocial interventions for autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 35*(6), 695-708.

Luyster, R., Gotham, K., Guthrie, W., Coffing, M., Petrak, R., Pierce, K., et al. (2009a). The Autism Diagnostic Observation Schedule-toddler module: a new module of a standardized diagnostic measure for autism spectrum disorders. *J Autism Dev Disord, 39*(9), 1305-1320.

Luyster, R., Gotham, K., Guthrie, W., Coffing, M., Petrak, R., Pierce, K., et al. (2009b). The Autism Diagnostic Observational Schedule- Toddler module: A new module of a standardized diagnostic measure of autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*, 1305-1320.

Matson, J., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 418-425.

Matson, J., Mahan, S., Fodstad, J. C., Hess, J. A., & Neal, D. (2010). Motor skills abilities in toddlers with autistic disorder, pervasive developmental disorder-not otherwise specified, and atypical development *Research in Autism Spectrum Disorders, 4*, 444-449.

Matson, J., & Sipes, M. (2010). Methods of early diagnosis and tracking for autism and Pervasive Developmental Disorder Not Othewise Specified (PDDNOS). *Journal of Developmental and Physical Disabilities, 22*, 343-358.

Mostofsky, S., Burgess, M. P., & Gidley Larson, J. C. (2007). Increased motor cortex white matter volume predicts motor impairment in autism. *Brain, 130*, 2117-2122.

Mostofsky, S., Powell, S., Simmonds, D., Goldberg, M., Caffo, B., & Pekar, J. (2009). Decreased connectivity and cerebellar activity in autism during motor task performance. *Brain, 132*(9), 2413-2425.

Mullen, E. (1995). *Mullen scales of early learning (AGS ed.)*. Circle Pines: MN: American Guidance Services.

National Research Council (NRC). (2001).

Ozonoff, S., Young, G. S., Goldring, S., Greiss-Hess, L., Herrera, A. M., Steele, J., et al. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorders, 38*, 644-656.

Provost, B., Heimerl, S., & Lopez, B. R. (2007). Levels of gross and fine motor development in young children with autism spectrum disorder. *Physical & Occupational Therapy in Pediatrics, 27*(3).

Provost, B., Lopez, B. R., & Heimerl, S. (2007). A comparison in motor delays in young children: Autism spectrum disorder, developmental delay, and developmental concerns. *Journal of Autism and Developmental Disorders, 37*, 321-328.

Rinehart, N., Tonge, B., Bradshaw, J., Iansek, R., Enticott, P., & Johnson, K. (2006). Movement related potential in high-functioning autism and Asperger's disorder. *Developmental medicine and child neurology, 48*, 272-277.

Rogers, S. (2000). Interventions that facilitate socialization in children with autism. *Journal of Autism and Developmental Disorders, 30*(5), 399-409.

Rogers, S., Hall, T., Osaki, D., Reaven, J., & Herbison, J. (2000). A comprehensive, integrated, educational, approach to young children with autism and their families *Preschool education programs for children with autism (2nd ed)*. Austin, TX: Pro-Ed.

Rogers, S., Hayden, D., Hepburn, S., Charlifue-Smith, R., Hall, T., & Hayes, A. (2006). Teaching young nonverbal children with autism useful speech: A pilot study of the denver modeland PROMPT interventions. *Journal of Autism and Development Disorders, 36*, 1007-1024.

Sparrow, S., Cicchetti, D., & Balla, D. (2005). *Vineland-II Adaptive Behavior Scales*. Circles Pines, MN.: American Guidance Service.

Staples, K., & Reid, G. (2009). Fundamental movement skills and autism spectrum disorders.

Sutera, S., Pandey, J., Esser, E. L., & Rosenthal, M. A. (2007). Predictors of optimal outcome in toddlers diagnosed with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 98-107.

Swiezy, N. (2008). Bridging for success in Autism: Training and collaboration across medical, educational, and community systems. *Child and adolescent psychiatric clinics of North America, 17*(4).

Teitelbaum, P., Teitelbaum, O., Nye, J., Fryman, J., & Maurer, R. G. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Psychology, 95*, 13982-13987.

Teittelbaum, P., Teittelbaum, O., Nye, J., Fryman, J., & Maurer, R. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Psychology, 95*, 13982-13987.

Trevarthen, C., & Daniel, S. (2005). Disorganized rhythm and synchrony: Early signs of Autism and Rett Syndrome. *Brain & Development, 27.*

Vernazza-Martin, S., Martin, N., Vernazza, A., Lepellec-Muller, A., Rufo, M., Massion, J., et al. (2005). Goal directed locomotion and balance control in autistic children. *Journal of Autism and Developmental Disorders, 35*(1), 91-102.

Vismara, L. A., Colombi, C., & Rogers, S. J. (2009). Can one hour per week of therapy lead to lasting changes in young childen with autism? *Autism, 13*(1), 93-115.

Wise, M. D., Little, A. A., Holliman, J. B., Wise, P. H., & Wang, J. (2010). Can state early intervention programs meet the increased demand of children suspected of having autism spectrum disorders? *Journal of Developmental and Behavioral Pediatrics, 31*(6).

Wong, V. C. N., & Kwan, Q. K. (2010). Randomized controlled trial for early intervention for autism: A pilot study of the autism 1-2-3 Project. *Journal of Autism and Developmental Disorders, 40*, 677-688.

Yirmiya, N., & Ozonoff, S. (2007). The very early autism phenotype. *Journal of Autism and Developmental Disabilities, 37*(1), 1-11.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience, 23*(2-3), 143-152.

Table Captions

Table 3.1. Descriptive characteristics of the participants.

Table 3.2. Average motor skill difference variable based on the difference between the motor age equivalent score and the child's chronological age.

Table 3.3. Correlation analysis of dependent variables.

Table 3.4. Analysis of covariance (ANCOVA) for Fine Motor Skills on Adaptive Behavior Composite and Daily Living Skills.

Table 3.5. Analysis of covariance (ANCOVA) of Fine Motor on Adaptive Social and Communicative Behavior

Table 3.6. Analysis of covariance (ANCOVA) for gross motor skills on adaptive behavior composite and daily living skills.

Table 3.7. Analysis of covariance (ANCOVA) for Gross Motor Skills on Adaptive Social and Communicative Behavior

Variable	Mean/ Frequency	N= 233
Age (months)	30.36 (5.9)*	
Gender	184M, 49F	
Race/ Ethnicity	157 Caucasian, 68 African American, 2 Asian American, 1 Native American, 3 Biracial, 7 Unspecified	
Maternal Education	39 Graduate/ Professional, 57 College, 66 Some College, 42 High School Diploma, 4 Some High School, 25 Unspecified	
Autism Diagnostic Classification	172 ASD, 22 PDD-NOS, 39 Non-ASD	
Gross Motor Age Equivalent	22.19 (6.7)	
Fine Motor Age Equivalent	19.52 (6.6)	
Visual Reception Age Equivalent	20.61 (6.1)	
Receptive Language Age Equivalent	11.72 (8.8)	
Expressive Language Age Equivalent	12.45 (7.8)	
Vineland Fine Motor Age Equivalent	18.64 (5.5)	
Vineland Gross Motor Age Equivalent	20.81 (6.6)	
Vineland Overall Motor Age Equivalent	19.83 (5.8)	

Vineland Standard Motor Score	74.20 (14.0)
Ratio Verbal IQ	40.19 (25.2)
Ratio Non-Verbal IQ	67.42 (21.4)

Table 3.1. Descriptive characteristics of the participants

*Mean (standard deviation)

Variable	ASD	PDD-NOS	non-ASD	Group (combined)
Gross motor difference variable (months)	8.8(7.6)	7.6(7.5)	6.5(7.6)	8.2 (7.6)*
Fine motor difference variable (months)	12.0(7.2)	8.6(6.4)	8.4(8.0)	10.8 (7.4)

Table 3.2. Average motor skill difference variable based on the difference between the motor age equivalent score and the child's chronological age.

*Mean (standard deviation)

	Adaptive Behavior	Daily Living	Social
Adaptive Behavior	-	-	-
Daily Living	.873*	-	-
Social	.830*	.642*	-
Communicative	.809*	.646*	.857*

Table 3.3. Correlation analysis of dependent variables.

* Significant relationship ($p < 0.001$)

	Adaptive Behavior Composite				Daily Living Skills			
	B	Std. Error	t	p	B	Std. Error	t	p
Intercept	83.12	2.45	33.87	<0.001	88.85	2.63	33.76	<0.001
Demographics								
Gender= M	.322	.946	.341	.734	2.40	1.02	2.35	<0.05
Gender= F	0				0			
Ethnicity= C	-1.57	1.06	-1.96	.051	-1.90	.86	-2.21	<0.05
Ethnicity= Other	0				0			
Age	-1.023	0.07	-15.61	<0.001	-1.07	.07	-15.15	<0.001
Diagnosis								
Autism	-6.40	1.06	-6.03	<0.001	-5.30	1.14	-4.66	<0.001
PDD-NOS	-6.21	1.30	-4.76	<0.001	-6.54	1.40	-4.68	<0.001
Non-Autism	0				0			
Measures								
Non-verbal problem solving	.178	.105	1.69	.091	.137	.112	1.22	.223
Fine motor age equivalent	.643	.109	5.92	<0.001	.644	.117	5.53	<0.001

Table 3.4. Analysis of covariance (ANCOVA) for Fine Motor Skills on Adaptive Behavior Composite and Daily Living Skills

	Social				Communication			
	B	Std. Error	t	p	B	Std. Error	t	p
Intercept	93.79	3.149	29.78	<0.001	83.28	3.16	26.39	<0.001
Measures								
Non-verbal problem solving	-.118	.031	-3.78	<0.001	.294	.135	2.18	<0.05
Fine motor age equivalent	-.063	.020	-3.23	<0.001	.387	.140	2.77	<0.01
Demographics								
Gender= M	-4.29	1.21	-3.54	<0.001	-3.25	1.22	-2.68	<0.01
Gender= F	0				0			
Ethnicity= C	-1.270	1.027	-1.24	.218	-.330	1.03	-.321	.749
Ethnicity= Other	0				0			
Age	-.911	.084	-10.83	<0.001	-.748	.084	-8.88	<0.001
Diagnosis								
Autism	-11.57	1.36	-8.50	<0.001	-10.71	1.37	-7.84	<0.001
PDD-NOS	-8.41	1.68	-5.02	<0.001	-7.92	1.68	-4.72	<0.001
Non-Autism	0				0			

Table 3.5. Analysis of covariance (ANCOVA) of Fine Motor on Adaptive Social and Communicative Behavior

	Adaptive Behavior Composite				Daily Living Skills			
	B	Std. Error	t	p	B	Std. Error	t	p
Intercept	83.31	2.61	31.93	<0.001	88.83	2.76	32.17	<0.001
Demographics								
Gender= M	.008	1.03	.008	.994	1.93	1.09	1.77	.079
Gender= F	0				0			
Ethnicity= C	-2.19	.838	-2.62	<0.01	-2.47	.888	-2.78	<0.01
Ethnicity= Other	0				0			
Age	-1.01	.069	-14.49	<0.001	-1.05	.07	-14.31	<0.001
Diagnosis								
Autism	-6.42	1.12	-5.7	<0.001	-5.34	1.19	-4.49	<0.001
PDD-NOS	-5.66	1.38	-4.1	<0.001	-5.97	1.46	-4.09	<0.001
Non-Autism	0				0			
Measures								
Non-verbal problem solving	.515	.088	5.87	<0.001	.438	.093	4.69	<0.001
Gross motor age equivalent	.247	.088	2.79	<0.01	.299	.094	3.18	<0.01

Table 3.6. Analysis of covariance (ANCOVA) for gross motor skills on adaptive behavior composite and daily living skills.

	Social				Communication			
	B	Std. Error	t	p	B	Std. Error	t	p
Intercept	94.94	3.23	29.33	<0.001	83.76	3.22	25.98	<0.001
Demographics								
Gender= M	-3.66	1.28	-2.86	<0.01	-3.13	1.28	-2.45	<0.05
Gender= F	0				0			
Ethnicity= C	-1.88	1.04	-1.81	.072	-.764	1.04	.463	0.461
Ethnicity= Other	0				0			
Age	-.877	0.86	-10.19	<0.001	-.730	.086	-8.52	<0.001
Diagnosis								
Autism	-11.42	1.39	-8.19	<0.001	-10.65	1.39	-7.67	<0.001
PDD-NOS	-8.12	1.71	-4.75	<0.001	-7.63	1.70	-4.48	<0.001
Non-Autism	0				0			
Measures								
Non-verbal problem solving	-.118	0.31	-3.78	<0.001	.568	.108	5.23	<0.001
Gross motor age equivalent	-.105	.110	-.954	0.341	.045	.109	.413	0.680

Table 3.7. Analysis of covariance (ANCOVA) for Gross Motor Skills on Adaptive Social and Communicative Behavior

Chapter 4

The effect of motor skills on the social communicative skills of school-aged children with autism spectrum disorders

Introduction

Autism spectrum disorder (ASD) is a pervasive developmental disorder characterized by deficits in social skills, communication and repetitive or restricted interests (American Psychiatric Association [APA], 1994). Recent prevalence statistics suggest that 1 in every 110 children are diagnosed with ASD (CDC, 2011; Matson & Kozlowski, 2011). Characteristics of children with ASD are present at a young age and are pervasive over time and age (Bellini, Peters, Benner, & Hopf, 2007; Gresham, Sugai, & Horner, 2001; Lord, 2000a; Lord et al., 2006; Luyster et al., 2009). Programs and services for school-aged children with ASD are focused on social communicative deficits and often packaged as a social skills program. Although there appear to be a plethora of social-skills based research in ASD literature, program efficacy along with the application of learned social skills beyond the treatment setting have come into question (Bellini & Peters, 2008; Bellini, et al., 2007; Chamberlain, Kasari, & Rotheram-Fuller, 2007; Kasari, Locke, Gulsrud, & Rotheram-Fuller, 2010; Kasari & Rotheram-Fuller, 2005; McConnell, 2002; Williams White, Keonig, & Scahill, 2007).

Best practice recommendations for social skills programs have been made based on clinical judgment and substantiated research (Elliott, Malecki, & Demaray, 2001; Gresham, et al., 2001; Kasari, et al., 2010; Rao, Beidel, & Murray, 2008). Program recommendations include the use of naturalistic settings and age-matched peers (Lord et al., 2005; Rao, et al., 2008). Nonetheless, one common limitation, of social skills programs, that has emerged is the generalization of learned skills beyond the treatment setting (Bellini & Peters, 2008; Bellini, et al., 2007; Gresham, et al., 2001). Very few social skills based interventions have had success in generalizing social skills beyond the treatment setting (Bellini & Peters, 2008; Bellini, et al., 2007; Elliott, et al., 2001). It is unclear whether current interventions can successfully adhere to this limitation and whether best practice recommendations that have been established address the need for generalization (Bellini & Peters, 2008; Bellini, et al., 2007; Gresham, et al., 2001). Regardless of these limitations, the importance of social skills programs for school-aged children with ASD has clearly been established (McConnell, 2002).

One avenue that has not been explored is the impact that motor skills play in the social development of children with autism. Recommendations, based on best-practice claim that skill practice is a critical piece to further apply learned skills beyond the treatment setting (Lord, 2000b; Rao, et al., 2008). For school-aged children practice might include school-based play or common schoolyard activities and these activities often require relatively proficient motor skills to participate with success (Berkeley, Zittel, Pitney, & Nichols, 2001; Ulrich, 2000). However, motor skill deficits are common amongst school aged children with ASD and may be hindering this type of practice (Berkeley, et al., 2001; Green et al., 2002; Green et al., 2009; Staples & Reid, 2009).

Motor skill deficits persist and are present in school-aged children with autism (Berkeley, et al., 2001; Staples & Reid, 2009). In a large, well-defined sample of children with autism (N= 101), 80% presented with motor skill deficits (Green, et al., 2009). Some research has suggested that the severity of the motor deficit is driven by intellectual ability, in other words, children with a lower IQ or developmental level have weaker motor skills (Green, et al., 2009). But, other studies suggest that the deficits cannot entirely be attributed to intellectual ability (Green, et al., 2002; Lloyd, MacDonald, & Lord, 2011). When a higher-functioning group of children with autism were compared to children with a motor skill specific disability, the children with autism had the weakest motor skills (Green, et al., 2002). This finding indicates the depth of motor deficits common in school-aged children with autism.

School-aged children with autism have deficits in locomotor and object-control skills based on the Test of Gross Motor Development- 2 (TGMD-2) (Berkeley, et al., 2001; Staples & Reid, 2009; Ulrich, 2000). The TGMD-2 assesses locomotor skills such as running, galloping, hopping, sliding, leaping and jumping as well as object-control skills such as overhand throwing, striking, kicking, underhand rolling, dribbling and catching (Ulrich, 2000). The skills tested on the TGMD-2 are considered essential skills needed in physical education and active play (Ulrich, 2000). In a more recent study using the TGMD-2, findings corroborated previous research and reemphasized that children with autism could perform the skills, but in a less mature form (Berkeley, et al., 2001; Morin & Reid, 1985; Staples & Reid, 2009). Staples & Reid (2009) used two control groups in their study, age-matched typically developed peers and children matched on the raw scores of the TGMD-2 (younger children). They concluded that children with autism had movement skills that were performed equivalent to children half of their chronological age (ie. 10 year old children with autism performed motor skills equivalent to a 5 year old). When 6- 10 year old children with Asperger's syndrome (a form of ASD) were compared to age-matched controls with a specific developmental disorder of motor function, greater motor deficits were found in the children with Asperger's syndrome (Green, et al., 2002). In other words children with autism had weaker motor skills than children with a disability determined by motor skill-deficits.

In some of the original clinical descriptions of what is now called autism, Asperger attached considerable weight to motor clumsiness (Frith, 1991). Why children with autism display deficits in motor skills is a question of interest for many researchers in the field. How ASD manifests and the neural system involvement is an ongoing area of study (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Mostofsky, Burgess, & Gidley Larson, 2007; Mostofsky et al., 2009).

Recent research has found that children with autism managed single motor tasks well, but deficits were present when chaining motor tasks into a global action (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). In short, more complex motor skills requiring a combination of actions, like object-control skills, were harder for children with ASD to execute. During simple motor tasks such as a finger tap exercise, the connectivity within the motor circuits was decreased in children with ASD using fMRI (Mostofsky, et al., 2009). Compared to typically developing controls, children with autism displayed similar neural connectivity during rest, but differences during a simple motor task were evident. Notably, the authors of this study discussed the brain area responsible for procedural acquisition of motor skills may also be important in language and social development, both of which are deficient areas in children with ASD and core diagnostic characteristics (Mostofsky, et al., 2009). Currently, the use of motor performance in ASD diagnosis is embedded in gestures, stereotypies and imitation (Gotham, Pickles, & Lord, 2009; Gotham, Risi, Pickles, & Lord, 2007; Lord, 2000a; Luyster, et al., 2009). However, descriptive studies have clearly indicated that motor skills deficits go beyond gestures, stereotypies and imitation (Berkeley, et al., 2001; Green, et al., 2002; Green, et al., 2009; Staples & Reid, 2009).

Although motor skill deficits are present in school-aged children with autism, the primary focus of intervention is on social communicative skills. The effectiveness of social skills programs range in nature and various methods of delivery have been implemented (Bellini & Peters, 2008; Bellini, et al., 2007; Gresham, et al., 2001). These methods include, but are not limited to prompting and rehearsal, play-based activities, free-play activities, reinforcement, modeling, storytelling and direct instruction (Vaughn et al., 2003). The importance of providing efficacious social programming for school-aged children with autism has clearly been established (McConnell, 2002). However, there is less agreement on the specific content of social skills programs (Bellini, et al., 2007; Gresham, et al., 2001; Kasari & Rotheram-Fuller, 2005). Researchers are still working on methods of "best practice", but for the most part literature supports programs that provide flexibility, naturalistic settings for skill practice and more than one group meeting per week (Elliott, et al., 2001; Gresham, et al., 2001; Lim, Kattapuram, & Lian, 2007; Rao, et al., 2008). Based on these recommendations it seems reasonable to believe that proficient motor skills may help in establishing optimal opportunities to practice social skills.

The purpose of this study is to determine whether the functional motor skills of 6-15 year old children with high-functioning autism, as measured by the Test of Gross Motor Development 2nd Edition (TGMD-2; Ulrich, 2000), predict success in a social skills based on standardized assessments. It is hypothesized that children with better motor skills will have better social skills.

Method

Participants. The Medical Institutional Review Board at the University of Michigan and the University of California- Los Angeles approved all methods and procedures for this study. The participants for this study were students in the Ann Arbor Public Schools and Los Angeles public schools. Permission to work within the Ann Arbor Schools was obtained from the superintendent, the head psychologist, principals of the selected schools and teachers whose students were eligible to participate in this study. All parents signed an informed consent prior to the start of the study. The participants were children with a clinical diagnosis of autism or pervasive developmental disorder-not otherwise specified (PDD-NOS), based on the Ann Arbor Public School and Los Angeles Public Schools ASD diagnostic criteria, and met diagnostic criteria for ASD or PDD-NOS based on the Autism Diagnostic Observational Schedule (ADOS) (Lord, 2000a). The participants were between the ages of 6- 15 years old with IQ scores above 64 and included in typical classrooms. None of the participants in this study had additional diagnoses of sensory or physical impairments.

Measurements

Assessments for the participants took place at the University of Michigan Autism and Communication Disorders Center (UMACC), an autism center at the Univeristy of

California- Los Angeles and in some cases the children's home. Teacher-based assessments and play observation took place at the participant's school.

Motor skill measurement. The motor skills of each participant were measured using the Test of Gross Motor Development 2nd Edition (TGMD-2; Ulrich, 2000). This test was used because it assesses common motor skills that are needed for successful play in physical education and playground settings (Ulrich, 2000). The TGMD-2 is divided into two common subtests: locomotor skills and object control skills. The locomotor subtest measures six gross motor skills that require fluid coordinated movement. The skills assessed are the run, gallop, hop, leap, horizontal jump and slide. The object-control subtest measures six gross motor skills assessing the child's ability to play with balls. The skills assessed are striking a stationary ball, stationary dribble, catch, kick, overhand throw and underhand throw. Once the child masters the skills on the TGMD-2, they are prepared to begin to learn how to use them in more sport specific activities. The TGMD- 2 is a norm-referenced test for children aged 3- 10 years old, but has been used frequently in older children, especially those with disabilities (Berkeley, et al., 2001; Morin & Reid, 1985; Staples & Reid, 2009). The raw scores on the TGMD-2 were used rather than the standardized norms given that some of the children in this study exceeded 10 years of age. Inter-rater reliability was established at 80% before the study began.

Child Diagnostic Measure. All participants had an educational classification of autism and a confirmatory diagnosis of autism or PDD-NOS was determined by administering the ADOS, a semi-structured standardized assessment of communication, social interaction and play (Gotham, et al., 2007; Lord, 2000a). Pre-established diagnostic algorithms and cut-points have been correlated to inform clinicians and researchers of diagnosis (Gotham, et al., 2007; Lord, 2000a). Each member of the research team established inter-rater reliability exceeding 80% exact agreement (kappa>0.60) for all ADOS items on three consecutive administrations before the study began.

Intelligence Quotient (IQ). The Standford-Binet Intelligence Scales, Fifth Edition (SB-5) was used to measure each participant's intelligence quotient (Roid, 2003). This assessment was used to ensure that the participants in this study had an IQ above 64. This test has been used previously for children in this age range to confirm IQ. All team members had experience and practice in administering this standardized test.

Measure of Social Skills. Teachers of the participants completed the Social Skills Improvement System Rating Scales (SSIS; Gresham & Elliott, 2008). A standard social score is derived from this tool based on social skills, problem behaviors and academic performance (Elliott, Gresham, Frank, & Beddow, 2008)

Data Reduction

All administrators strictly adhered to the standardized procedures outlined in each respective test manual. As indicated in the measurement description, inter-rater reliability was established for the TGMD-2 and ADOS. Autism cut-off was based on standardized up-to-date revised algorithms (Gotham, et al., 2007). These algorithms included scores based on social communication, repetitive and restricted interests and stereotyped behaviors. Calibrated autism severity was calculated based on standardized algorithms (Gotham, et al., 2009). The SB-5 was administered by experienced assessors and the SSIS was a standardized form filled out by the participant's teachers. Raw scores from the TGMD-2 were used for analysis because some of the participants exceeded the age of the norm-referenced motor scores. Raw total, locomotor & object-control scores were used for the purpose of analysis. Descriptive characteristics of the sample included age, gender and ethnicity. A diagnosis of autism or PDD-NOS was obtained and reported based on the participant's standard ADOS score and a standard IQ was derived from the SB-5 and reported as such.

Data Analysis

Data analysis tested the effect of motor skills measured by the TGMD-2 on the standard social skills of children with ASD as indicated by SSIS and the calibrated autism severity. ANCOVA was used to test the relationship of motor skills on social communicative skills holding constant age, IQ, ethnicity, gender and autism diagnosis. It is hypothesized that children with higher motor skills based on the raw scores indicated on the TGMD-2 will have more success in social communicative skills as indicted through standard scores on the SSIS and calibrated autism severity scores.

Results

Thirty-five participants with a confirmed diagnosis of ASD (N= 23) or PDD-NOS (N=12) were included in this study (mean age 9.2 (±2.5) years). Descriptive characteristics of the sample can be found in Table 4.1.

Influence of Motor Skills on Calibrated Severity

Analysis of covariance (ANCOVA) fitting total raw motor skills indicated by the TGMD-2 (Ulrich, 2000), IQ, age, gender, ethnicity and autism diagnosis was performed on the calibrated autism severity (Gotham et al., 2009). There were no significant interactions. Total raw motor skill scores were not a significant predictor of calibrated autism severity. The only significant predictor in this model was gender ($p < 0.05$) (see

Table 4.2). ANCOVA was performed on subscales of the TGMD-2, the locomotor subscale and the object-control subscale. The locomotor subscale did not predict calibrated autism severity. The only predictor in this model, fitting locotmotor raw scores, IQ, age, gender, ethnicity and autism diagnosis was gender ($p \leq 0.05$) (see Table 4.3). When ANCOVA was performed on subscale of object-control, motor skills were a significant predictor of calibrated autism severity ($p < 0.05$) (Table 4.4). The other predictor in this model was gender ($p < 0.05$).

Influence of Motor Skills on the standardized social skills of school-aged children with Autism

Analysis of covariance (ANCOVA) fitting total raw motor skills scores, IQ, age, gender, ethnicity and autism diagnosis was performed and the standardized social skills as indicated through the social skills skills improvement system (SSIS) (see Table 4.5). There were no significant interactions. ANCOVA was performed on subscales of the TGMD-2, the locomotor subscale and the object-control subscale. The locomotor subscale did not predict standardized social skills (see Table 4.6). ANCOVA was performed on subscale of object-control, motor skills were not a significant predictor of standardized social skills (see Table 4.7 and Figure 4.1).

Discussion

School-aged children with autism have consistently performed poorly on standardized tests of motor skills (Berkeley, et al., 2001; Green, et al., 2002; Green, et al., 2009; Staples & Reid, 2009). This study corroborated previous research as school-aged children with autism performed poorly on the TGMD-2, a standardized test of motor skills (Ulrich, 2000). Although motor skills have gained recognition in autism literature, the focus of intervention for school-aged children has been on social skill development (McConnell, 2002). When the locomotor skills and object control skills were combined into a total standardized motor score there was no relationship to calibrated autism severity or standardized social skills. When the locomotor and object control motor skills were analyzed separately the locomotor skills were not predictive of calibrated autism severity or standardized social skills. However, the object control skills of the same group of children were significantly predictive of calibrated autism severity holding other important variables constant ($p < 0.05$).

Calibrated autism severity scores have been indicated as optimal for comparisons of assessments across time (and age), and to identify different trajectories of autism severity independent of verbal IQ (Gotham, et al., 2009). Motor skills of school-aged children with autism have never been used as criteria in the prediction of calibrated autism severity. The significant relationship of standardized object-control skills sheds light on to the importance of motor skills. Children with weaker object control skills, based on the TGMD-2 (Ulrich, 2000), had higher calibrated severity scores (indicative of more severe autism symptomology) (Gotham et al., 2009).

Previously, ASD "severity" was subjective and frequently used outcome variables included language delay, cognitive function, behavioral issues and raw scores from the ADOS (Lovaas, 1987; Sutera, Pandey, Esser, & Rosenthal, 2007). However, none of these stand-ins constitute valid and reliable methods of severity assessment. The calibrated severity scores were mapped based on ADOS raw scores, which represent core deficits specific to the social communicative domain and the basis of ASD characteristics. These deficits of social skills, communication and repetitive behaviors or restricted interests were based on the standardized semi-structured interview, administered to the individuals through presses (a common term used in the ADOS, a press is based on the manualized protocol for ADOS administration) meant to obtain and give opportunity for social communication based on age and language level (Lord, 2000a). The calibrated severity scores were calculated independent of cognitive function (Gotham, et al., 2009). In other words, cognitive function is not indicative of ASD severity. The relationship of object-control skills to calibrated autism severity may help to better understand autism as a whole, and further how motor skills influence social skills and the core characteristics of autism.

The social deficits of school-aged children with autism are the hallmark characteristic of autism and the primary focus of intervention (Machalicek et al., 2008; Williams White, et al., 2007). However, only minimally effective social skill improvements have been found (Bellini, et al., 2007). Generally, it appears that some immediate social change occurs, but longitudinal social change is weak and generalizing learned skills over time was undoubtedly a limitation of social communicative interventions. Regardless of the limitations to current social skills research, it has been established that social skills interventions are a necessity in any educational program for children with autism, based on the extensive social deficits experienced in this group (Lord, 2000a; Lord, et al., 2005; McConnell, 2002).

Since object-control skills map on to the calibrated severity of autism, and since calibrated severity captures the social communicative deficits of this group of children, it is possible that improved motor skills may impact social communicative success. Behaviorally higher levels of social communicative success have been established when children participate in games on the playground. For example, children participating in sports like soccer, or games like four-square (a common ball-game on the playground), are ranked in the highest category of social communicative success (Kasari, et al., 2010). It is less clear whether children's lack of participation in movement games on the playground are due to deficits in motor skills, or whether or not the social aspect of the game is too complex or intimidating. Creating successful environments for children to practice social skills is important and for school-aged children the playground is an important avenue to explore. How improved motor skills may impact this avenue of social skill generalization is an area of future research.

Although motor skills did not predict standardized social skills in this same group, there is a need to further established assessments that capture changes based on intervention (Matson & Wilkins, 2009). Finding measures with strong sensitivity and specificity are a necessity (Gotham et al., 2009). Currently, the calibrated autism severity scores are the closest measure to capture the core social communicative characteristics with necessary specificity and sensitivity (Gotham et al, 2009).

Limitations

Standardized measures of social skills are important. However, social skills are often measured differently across studies. A more standardized and sensitive measure of social change would be optimal for this study. Calibrated severity is independent of IQ, however, children with autism have a broad range of IQ and this particular study was limited to children with IQ above 64. A more comprehensive study would include children with autism, regardless of IQ scores.

Future Research

Future research needs to further explore how motor skills and social skills are related. Learning how motor skills map onto social change and whether or not improved motor skills correspond with positive social development is an area of future study. Social skills are a priority in autism research. But, understanding other factors that may impact social success is important. Content of social skills intervention has been questioned and motor skills have not been included in the discussion. Yet, a relationship exists. Understanding the impact of this relationship needs to be explored further.

Conclusion

School-aged children with autism have both motor skill and social skill deficits. The hallmark characteristic of autism is deficits in the social communicative domain. This study provides an initial relationship between motor skills and social communicative skills as indicated through the calibrated severity scores. Children with weaker motor skills have higher calibrated severity scores. How this relationship exists behaviorally, and from a social skills programming perspective needs to be explores further. However, given the necessity of social skills programs for school-aged children with autism and the broader need to explore specific social skills content, motor skills need to be included in the discussion.

References

American Psychiatric Association (APA). (1994). *Diagnostic and statistical manual of mental disorders (DSM-IV)* (4^{th} ed.). Washington, D.C: APA.

Bellini, S., & Peters, J. (2008). Social skills training for youth with autism spectrum disorder. *Child and adolescent psychiatric clinics of North America, 17*(4), 857-873.

Bellini, S., Peters, J., Benner, L., & Hopf, A. (2007). A meta-analysis of school-based social skills interventions for children with autism spectrum disorders. *Remedial and Special Education, 28*(3), 153-162.

Berkeley, S. L., Zittel, L. L., Pitney, L. V., & Nichols, S. E. (2001). Locomotor and object control skills of children diagnosed with autism. *Adapted Physical Activity Quarterly, 18*(4), 405-416.

Center for Disease Control and Prevention (CDC). (2011).

Chamberlain, B., Kasari, C., & Rotheram-Fuller, E. (2007). Involvement or isolation? The social networks of children with autism in regular classrooms. *Journal of autism and developmental disorders, 37*, 230-242.

Elliott, S., Gresham, F., Frank, J., & Beddow, P. (2008). Intervention validity of social behavior rating scales: features of assessments that link results to treatment plans. *Assessment for effective intervention, 34*(1), 15-24.

Elliott, S., Malecki, C., & Demaray, M. (2001). New directions in social skills assessment and intervention for elementary and middle school students. *Exceptionality, 9*(1&2), 19-32.

Fabbri-Destro, M., Cattaneo, L., Boria, S., & Rizzolatti, G. (2009). Planning action in autism. *Experimental Brain Research, 192*(3), 521-525.

Fournier, K., Hass, C., Naik, S., Lodha, N., & Cauraugh, J. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Development Disorders, 40*(10), 1227-1240.

Frith, U. (1991). *Autism and Asperger syndrome*. Cambridge: Cambridge University Press.

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(5), 693-705.

Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for improved validity. *Journal of Autism and Development Disorders, 37*(4), 613- 627.

Green, D., Baird, G., Barnett, A. L., Henderson, L., Huber, J., & Henderson, S. E. (2002). The severity and nature of motor impairment in asperger's syndrome: A comparison with specific developmental disorder of motor function. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 43*(5), 655-668.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., et al. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine and Child Neurology, 51*(4), 311-316.

Gresham, F., Sugai, G., & Horner, R. (2001). Interpreting outcomes of social skills training for students with high-incidence disabilities. *Exceptional Children, 67*(3), 331-344.

Kasari, C., Locke, J., Gulsrud, A., & Rotheram-Fuller, E. (2010). Social networks and friendships at school: Comparing children with and without ASD. *Journal of Autism and Developmental Disorders.*

Kasari, C., & Rotheram-Fuller, E. (2005). Current trends in psychological research on children with high-functioning autism and Asperger disorder. *Current Opinion in Psychiatry, 18*, 497-501.

Lim, S., Kattapuram, A., & Lian, W. (2007). Evaluation of a pilot cilnic-based social skills group. *The British Journal of Occupational Therapy, 70*(1), 35-39.

Lloyd, M., MacDonald, M., & Lord, C. (2011). The motor skills of toddlers with autism spectrum disorders. *Autism*, 1-18.

Lord, C. (2000a). The Autism Diagnostic Observation Schedule- Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3).

Lord, C. (2000b). Commentary: Achievments and future directions for intervention research in communication and autism spectrum disorders. *Journal of Autism and Developmental Disorders, 30*(5).

Lord, C., Risi, S., DiLavore, R., Shulman, C., Thurm, A., & Pickles, A. (2006). Autism from 2 to 9 years of age. *Archives of General Psychiatry, 63*, 694-701.

Lord, C., Wagner, A., Rogers, S., Szatmari, P., Aman, M., Charman, T., et al. (2005). Challenges in evaluating psychosocial interventions for autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 35*(6), 695-708.

Lovaas, O. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychiatry, 55*(1), 3-9.

Luyster, R., Gotham, K., Guthrie, W., Coffing, M., Petrak, R., Pierce, K., et al. (2009). The Autism Diagnostic Observational Schedule- Toddler module: A new module of a standardized diagnostic measure of autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*, 1305-1320.

Machalicek, W., Oreilly, M., Beretvas, N., Sigafoos, J., Lancioni, G., Sorrells, A., et al. (2008). A review of school-based instructional interventions for students with autism spectrum disorders. *Research in Autism Spectrum Disorders, 2*(3), 395-416.

Matson, J., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 418-425.

McConnell, S. (2002). Interventions to facilitate social interactions for young children with autism: Review of available research and recommendations for educational intervention and future research. *Journal of Autism and Developmental Disorders, 35*(5), 351-372.

Morin, B., & Reid, G. (1985). A quantitative and qualitative assessment of autistic individuals on selected motor tasks. *Adapted Physical Activity Quarterly, 2*(1), 43-55.

Mostofsky, S., Burgess, M. P., & Gidley Larson, J. C. (2007). Increased motor cortex white matter volume predicts motor impairment in autism. *Brain, 130*, 2117-2122.

Mostofsky, S., Powell, S., Simmonds, D., Goldberg, M., Caffo, B., & Pekar, J. (2009). Decreased connectivity and cerebellar activity in autism during motor task performance. *Brain, 132*(9), 2413-2425.

Rao, P., Beidel, D., & Murray, M. (2008). Social skills interventions for children with aspergers syndrome or high-functioning autism: A reivew and recommendations. *Journal of Autism and Developmental Disorders, 38*(2), 353-361.

Roid, G. (2003). *Stanford-Binet Intelligence Scales- Fifth Edition (SB5)*. New York, New York: Thompson Nelson.

Staples, K., & Reid, G. (2009). Fundamental movement skills and autism spectrum disorders.

Sutera, S., Pandey, J., Esser, E. L., & Rosenthal, M. A. (2007). Predictors of optimal outcome in toddlers diagnosed with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 98-107.

Ulrich, D. (2000). *Test of Gross Motor Development* (2nd Edition ed.). Austin, Texas: Pro-Ed.

Vaughn, S., Kim, A., Morris Sloan, C., Hughes, M., Elbaum, B., & Sridhar, D. (2003). Social skills interventions for young children with disabilities. *Remedial and Special Education, 24*(1), 2-15.

Williams White, S., Keonig, K., & Scahill, L. (2007). Social skills development in children with autism spectrum disorders: a review of the intervention research. *Journal of Autism Developmental Disorder, 37*(10), 1858-1868.

Table Captions

Table 4.1. Descriptive characteristics of the participants.

Table 4.2. Analysis of covariance (ANCOVA) for TGMD-2 total scores (raw scores) on Calibrated Severity of Autism.

Table 4.3. Analysis of covariance (ANCOVA) for TGMD-2 locomotor scores (raw scores) on Calibrated Severity of Autism.

Table 4.4. Analysis of covariance (ANCOVA) for TGMD-2 object control scores (raw scores) on Calibrated Severity of Autism.

Table 4.5. Analysis of covariance (ANCOVA) for TGMD-2 total scores (raw scores) on standardized social skills.

Table 4.6. Analysis of covariance (ANCOVA) for TGMD-2 locomotor scores (raw scores) on standardized social skills.

Table 4.7. Analysis of covariance (ANCOVA) for TGMD-2 object control (raw scores) on standardized social skills.

Variable	Mean/ Frequency	N= 35
Age (years)	9.2(2.5)	
Gender	25M, 10F	
Race/ Ethnicity	21 Caucasian, 2 African American, 8 Hispanic, 4 Asian American	
Autism Diagnostic Classification	23 ASD, 12 PDD-NOS	
Test of Gross Motor Development- Total	61.1(12.7)	
Test of Gross Motor Development- Locomotor	30.9(8.0)	
Test of Gross Motor Development- Object Control	30.2(6.6)	
IQ- Stanford Binet	94.77(19.88)	

Table 4.1. Descriptive characteristics of the participants

*Mean (standard deviation)

	B	Std. Error	t	p
Intercept	11.69	5.5	2.1	< 0.05
Demographics				
Gender= M	2.8	1.3	2.1	≤0.05
Gender= F	0			
Ethnicity= African American	-2.8	3.0	-.9	.354
Ethnicity= Caucasian	-3.9	2.3	-1.7	.107
Ethnicity= Hispanic	-2.5	3.0	-.8	.425
Ethnicity= Other	0			
Age	.132	.168	.787	.443
Diagnosis				
Autism	2.5	1.4	.7	.250
PDD-NOS	0			
Measures				
IQ	-.049	.031	-1.5	.141
Total motor skills (raw scores)	-.039	.036	-1.07	.301

Table 4.2. Analysis of covariance (ANCOVA) for TGMD-2 total scores (raw scores) on Calibrated Severity of Autism.

	B	Std. Error	t	p
Intercept	10.85	5.5	1.9	.064
Demographics				
Gender= M	2.8	1.3	2.1	$\leq$0.05
Gender= F	0			
Ethnicity= African American	-3.1	2.9	-1.0	.310
Ethnicity= Caucasian	-3.7	2.3	-1.6	.128
Ethnicity= Hispanic	-2.8	3.0	-.95	.352
Ethnicity= Other	0			
Age	.092	.171	.54	.597
Diagnosis				
Autism	2.5	1.3	.72	.253
PDD-NOS	0			
Measures				
IQ	-.055	.031	-1.76	.096
Locotmotor motor skills (raw scores)	-.008	.053	-.158	.877

Full Model

Table 4.3. Analysis of covariance (ANCOVA) for TGMD-2 locomotor scores (raw scores) on Calibrated Severity of Autism.

	B	Std. Error	t	p
Intercept	12.33	4.8	2.55	<0.05
Demographics				
Gender= M	2.88	1.18	2.42	<0.05
Gender= F	0			
Ethnicity= African American	-1.29	2.78	-.466	.648
Ethnicity= Caucasian	-3.44	2.1	-1.6	.121
Ethnicity= Hispanic	-1.42	2.76	-.516	.614
Ethnicity= Other	0			
Age	.186	.153	1.21	.243
Diagnosis				
Autism	2.5	1.4	.7	.250
PDD-NOS	0			
Measures				
IQ	-.036	.029	-1.2	.232
Object control (raw scores)	-.162	.073	-2.20	< 0.05

Full Model

Table 4.4. Analysis of covariance (ANCOVA) for TGMD-2 object control scores (raw scores) on Calibrated Severity of Autism.

	B	Std. Error	t	p
Intercept	103.38	30.67	3.37	.004
Demographics				
Gender= M	3.6	7.5	.482	.636
Gender= F	0			
Ethnicity= African American	-7.3	16.6	-.442	.665
Ethnicity= Caucasian	-6.4	13.04	-.491	.631
Ethnicity= Hispanic	16.12	16.87	.955	.355
Ethnicity= Other	0			
Age	-.390	.945	-.413	.686
Diagnosis				
Autism	-2.44	14.28	-.171	.867
PDD-NOS	0			
Measures				
IQ	.261	.176	1.49	.158
Total motor skills (raw scores)	-.195	.205	-.952	.356

Table 4.5. Analysis of covariance (ANCOVA) for TGMD-2 total scores (raw scores) on standardized social skills

	B	Std. Error	t	p
Intercept	100.14	31.17	3.2	<0.01
Demographics				
Gender= M	3.8	7.6	.5	.624
Gender= F	0			
Ethnicity= African American	-9.6	16.76	-.573	.575
Ethnicity= Caucasian	-6.8	13.36	-.512	.616
Ethnicity= Hispanic	14.18	16.99	.835	.417
Ethnicity= Other	0			
Age	-.523	.945	-.554	.588
Diagnosis				
Autism	2.5	1.3	.72	.253
PDD-NOS	0			
Measures				
IQ	.236	.176	1.34	.199
Locotmotor motor skills (raw scores)	-.179	.306	-.584	.568

Table 4.6. Analysis of covariance (ANCOVA) for TGMD-2 locomotor scores (raw scores) on standardized social skills

	B	Std. Error	t	p
Intercept	103.07	29.53	3.4	<0.05
Demographics				
Gender= M	4.08	7.3	.563	.582
Gender= F	0			
Ethnicity= African American	-2.66	16.98	-.157	.877
Ethnicity= Caucasian	-4.42	12.83	-.345	.735
Ethnicity= Hispanic	18.98	16.88	1.12	.280
Ethnicity= Other	0			
Age	.186	.153	1.21	.243
Diagnosis				
Autism	-4.05	14.15	-.286	.779
PDD-NOS	0			
Measures				
IQ	.293	.177	1.65	.118
Object control (raw scores)	-.559	.448	-.125	.232

Table 4.7. Analysis of covariance (ANCOVA) for TGMD-2 object control scores (raw scores) on standardized social skills

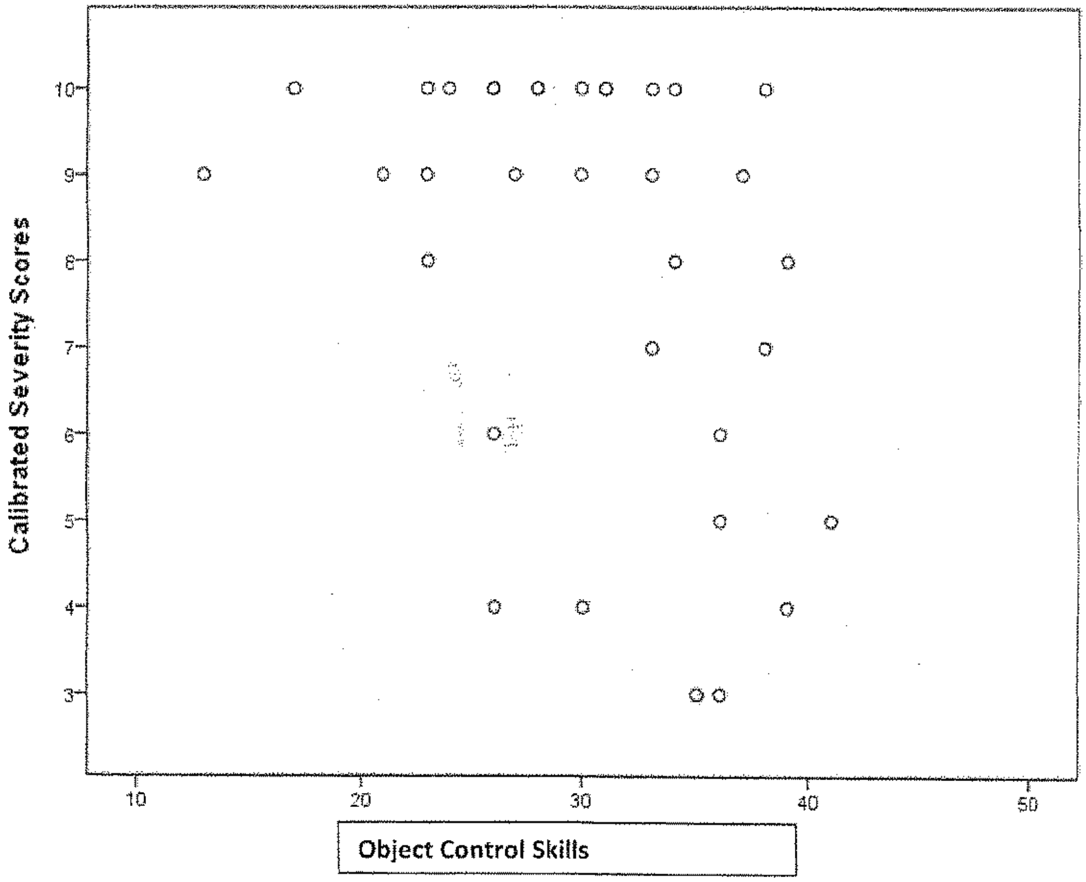

Figure 4.1. Calibrated Autism Severity Scores and Object Control Skills in school aged children with autism.

Chapter 5

Conclusion

Autism spectrum disorder (ASD) is a pervasive developmental disorder characterized by deficits in social skills, communication and repetitive or restricted interests (APA, 1994). Recent prevalence statistics suggest that 1 in every 110 children are diagnosed with ASD (CDC, 2011; Matson & Kozlowski, 2011). Diagnostic measures have been standardized and can identify children with autism at a very young age (Gotham, Risi, Pickles, & Lord, 2007; Luyster et al., 2009; NRC, 2001). The continuous rise in ASD diagnosis has been the focus of controversy, based on the 17% annual increase. Prevalence has also been a highly debated topic in the field of autism since research suggests genetic links and promotes behavioral interventions while parent groups have brought public awareness to vaccinations and other theories that have not been thoroughly researched. The rate of diagnosis and the current statistics make autism one of the most frequent childhood neurodevelopmental disorders (Fombonne, 2009; Matson & Kozlowski, 2011).

Coinciding with the core characteristics of the disorder are behavioral interventions driven by the hope of improving social communicative deficits. In fact learning social strategies to navigate the more general social world are critical skills for everyone, but particularly important tools for individuals with ASD to learn. The need for focused interventions teaching social communicative skills to individuals of all ages is one of the most important behavioral methods indicated in positive prognosis (Kelley, Naigles, & Fein, 2010). When the social trajectories of children with autism, PDD-NOS and non-autism developmental disabilities were studied longitudinally from ages 2-13 years, the social gap significantly widened as children aged (Anderson, Oti, Lord, & Welch, 2009). For young children social communicative interventions have been successfully implemented in the home and clinic settings through early intervention (Dawson et al., 2010; Kasari et al., 2005; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Wong & Kwan, 2010). In older children with autism, clinic and school-based programs are often packaged as a social skills program (Bellini & Peters, 2008; Bellini, Peters, Benner, & Hopf, 2007; Gresham, Sugai, & Horner, 2001; McConnell, 2002). Early intervention has been indicated as a priority in autism research and social skills programs for older-children with autism have also been indicated as a necessity (Frankel et al., 2010; Kasari, et al., 2005; McConnell, 2002).

Although a rather underexplored area of research, the motor skills of children with autism, have started to gain attention (Green et al., 2002; Green et al., 2009; Lloyd, MacDonald, & Lord, 2011; Matson, Mahan, Fodstad, Hess, & Neal, 2010; Staples & Reid, 2009). Based on descriptive studies deficits in motor skills are apparent in many children at a young age, but persistent and pervasive with age (Green, et al., 2002; Green, et al., 2009; Lloyd, et al., 2011; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). Most studies evaluating motor skill deficits are descriptive and methods of improving motor skills in children with autism have not been published. On the other hand, the hallmark characteristic of autism may overshadow the motor skill deficits that have been recognized and without doubt interventions for children with autism have been driven by social communicative deficits (Dawson, et al., 2010; Frankel, et al., 2010; Gresham, et al., 2001; Kasari, et al., 2005; Laugeson, Frankel, Mogil, & Dillon, 2009; McConnell, 2002).

Although the presence of both social communicative deficits and motor skill deficits are present and persistent in individuals with ASD, research rarely focuses on the interaction of these characteristics. In young children with autism spectrum disorder, there has been some acknowledgement that more proficient motor skills may be helpful to further success in early intervention (Lloyd, et al., 2011; Sutera, Pandey, Esser, & Rosenthal, 2007). In a large clinical sample of young children with autism motor skill deficits became worse as very young children aged (young children between the ages of 12- 36 months) (Lloyd, et al., 2011). How these wide deficits impact the use of motor skills in early interventions has yet to be explored. However, given the types of games and play-based activities used in early intervention, it seems likely that insufficient motor skills may impact children's participation and ultimately impact early intervention success.

The results of this dissertation indicate large motor skills deficits in young children with autism spectrum disorder. On average fine motor skill deficits were approximately 12 months behind the chronological age of the child, and gross motor skill deficits were approximately 9 months behind the expected chronological age of the child. These deficits and the wide age difference between the performance of motor skills and the children's age-equivalent scores, it is possible that motor skills could impact success in play-based activities, common in early intervention. It has been clearly indicated that early intervention is successful for young children with autism (Bellini & Peters, 2008;

Bellini, et al., 2007; Kasari, et al., 2005; McConnell, 2002). However, there is less agreement on the content of such programs, and one area that has been particularly underexplored is the role of motor skills in social communicative programming (Lloyd, et al., 2011; Sutera, et al., 2007).

The results of this study show that motor skill deficits directly map onto daily living skills, adaptive social & communicative skills and the calibrated severity of young children with autism. The relationship in this large clinical sample of young children with autism further strengthens the potential association of motor skill intervention in combination with, or alongside current early intervention content. Evidence clearly indicates that early intervention works, and is essential in the early care of young children with autism (Dawson, et al., 2010; Kasari, Freeman, & Paparella, 2006; Kasari, et al., 2005; Kasari, Gulsrud, et al., 2010; Kasari, Paparella, Freeman, & Jahromi, 2008; NRC, 2001). However, which mode of early intervention works best, or the content of early intervention is less agreed upon (Kasari, et al., 2006; Kasari, et al., 2005). The use of motor skills has not been reported as a specific feature of current early intervention programs that are receiving attention in autism research. The closest intervention that appears to successfully intertwine motor skills and early intervention is the Denver model (Rogers et al., 2006). Coincidently, this particular model of early intervention was recognized as a major contribution towards autism research from a behavioral intervention perspective (Dawson, et al., 2010). Yet the direct impact of how motor skill proficiency relates to this particular intervention was not studied.

In older children with autism, the relationship is less apparent. However, this also begs the question as to whether or not measures of social communication are sensitive enough to establish change. In addition, the motor skills of this group of school-aged children were well-below norms set for much younger children (Ulrich, 2000). Although the distribution of motor skills may pose problems in interpreting social communicative relationships, the motor skills deficits were clearly indicated, and corroborated previous research (Berkeley, Zittel, Pitney, & Nichols, 2001; Staples & Reid, 2009). Of note motor skills have already been indicated as important factors in ranking social communicative behavior, but not necessarily acknowledged accordingly (Kasari, Locke, Gulsrud, & Rotheram-Fuller, 2010). Behaviorally higher levels of social communicative success have been established when children participate in games on the playground. For example, children participating in sports like soccer, or games like four-square (a common ball-game on the playground), are ranked in the highest category of social communicative success (Kasari, Locke, et al., 2010). It is less clear whether children's lack of participation in movement games on the playground are due to deficits in motor skills, or whether or not the social aspect of the game is too complex or intimidating. Regardless, creating successful environments for children to practice social skills is important and for school-aged children the playground is an important avenue to explore. How improved motor skills may impact this avenue of social skill generalization is an area of future research.

Future research needs to continue exploring relationships between social communicative skills and motor skills. In addition, interventions aimed at improving motor skills need to be implemented. Group-based motor skill interventions focused on play may act positively on the motor skill success of children with autism, but this may also impact children's success in the social communicative domain. Based on the results of this study, the strongest relationships between motor skill deficits and social communication skills are apparent in young children with autism. Although focused on implementing change with this young group, we cannot neglect the needs of school-aged children with autism who are often underserved from a programming perspective.

As the most frequent neurodevelopmental disorder, autism has been gaining attention. Descriptive studies have started to recognize the frequency of motor skill deficits in this group (Lloyd, et al., 2011; Staples & Reid, 2009; Teitelbaum, et al., 1998). Older children have performed poorly on standardized motor skills tests, including significant deficits in object-control skills (ball skills) and locomotor skills (such as running and galloping) (Berkeley, et al., 2001; Morin & Reid, 1985; Staples & Reid, 2009). In some studies children with autism have met the criteria for developmental coordination disorder, a disorder defined by deficits in the fine and gross motor skills (Green, et al., 2002; Green, et al., 2009). In some of the original descriptions of autism, "clumsiness" was mentioned. However, clinically, the focus of motor skills deficits for children with autism has focused on stereotypies and imitation skills (Gotham, et al., 2007; Lord, 2000; Luyster, et al., 2009). Consequently, it appears that motor skills have been relatively underexplored from and intervention perspective.

This study acts as an initial step towards indicating the priority of motor skill intervention and potential relationship of this improvement towards ultimately improving the social communicative skills of children with autism. This relationship raises more questions and needs to be explored further. It is possible that improving motor skills may also map onto social communicative skills and calibrated autism severity.

Early intervention has gained a lot of attention in autism research based on the successes, and very young children are making very exciting improvements (Dawson, et al., 2010). Unfortunately social skills programs for older children with autism have not had the same magnitude of success. As children age, the social world becomes more complex (Gresham, et al., 2001). The premise of social skills programs for school-aged children is also focused on social communication, but the use of age-appropriate social communicative interventions are important considerations (Kasari, Locke, et al., 2010). Although improvements in social skills have been indicated in programs for school-aged children, generalizing learned skills in months following or even beyond the treatment setting is difficult (Bellini & Peters, 2008; Bellini, et al., 2007; McConnell, 2002). In school-aged children with autism, object-control skills directly mapped on to the calibrated severity of autism. Clearly, motor skill deficits are present in this group of children and now there is a directly relationship of weak motor skills to higher calibrated severity and poorer social skill performance. Previous research suggests that school-age children performed motor skills equivalent to half of their age (Staples & Reid, 2009). Other studies have clearly indicated that deficits exist in motor skills and are persistent with age (Green, et al., 2002; Green, et al., 2009). In fact, one study comparing children with autism to children with motor skill-specific deficits indicated that children with autism had worse motor skills (Green, et al., 2002). The importance of adapted physical education and motor skill instruction for this group of children should be aimed at improving basic motor skills. How improvements map on to improved social skills is an area of future research and potentially an avenue to further explore in relation to social skills programming. The results of this study are not different from social communicative results for other studies looking at young children with autism and school-aged children with autism. This study found that motor skills were significant predictors in the social communicative domain of young children, coinciding with social communicative changes commonly found in young children with autism. On the other hand, only one relationship was found for school-aged children with autism, object-control skills directly mapped onto the calibrated autism severity scores. Likewise, social skills program for school-aged children, although necessary, have indicated less success than that of early intervention programs focused on young children with autism spectrum disorder.

It is possible that these lines of research are not aligned, but theoretically, improving motor skills seems like a relatively novel area to study changes in social communicative behavior as it relates to children with autism spectrum disorder. We are learning more about autism through research every day. Understanding how motor skills influence or fit into the autism phenotype is important. Calibrated autism severity scores are the most specific and sensitive measures that we have in respect to autism symptomology (Gotham, Pickles, & Lord, 2009). This study shows that for young children and school-aged children a relationship exists. Exploring this relationship over time, longitudinally in the same group of children is important and another step in better understanding this relationship

Future research

Motor skills are an important area of study in regards to learning more about autism spectrum disorder. Future research needs to further explore this relationship, and better understand how motor skills may impact social communicative programs, for both young children with autism and school-aged children with autism. Not only does this question need to be explored further from a social communicative perspective, but also from the perspective of improving motor skills. It is possible that programs aimed at improving motor skills may also provide opportunities to learn some of the social communicative skills aimed at improvement through early intervention and social skills programs. Future research needs to study whether or not motor skills can be improved and whether or not motor skills improvements are related to social communicative success, including the generalization of social skills to beyond the treatment setting.

Conclusion

Motor skill deficits are related to the social communicative skills of young children and school-aged children with autism. Interventions aimed at improving motor skills may also impact the social communicative success of children with autism spectrum disorder. The relationship of motor skills with the hallmark characteristic of autism, social communicative deficits, needs to be taken seriously. The content of social communicative programs is under consideration and motor skill interventions needs to be a part of the discussion.

References

Anderson, D., Oti, R., Lord, C., & Welch, K. (2009). Patterns of growth in adaptive social abilities among children with autism spectrum disorders. *Journal of Abnormal Child Psychology, 37*(7), 1019-1034.

American Psychiatric Association (APA). (1994). *Diagnostic and statistical manual of mental disorders (DSM-IV)* (4th ed.). Washington, D.C: APA.

Bellini, S., & Peters, J. (2008). Social skills training for youth with autism spectrum disorder. *Child and adolescent psychiatric clinics of North America, 17*(4), 857-873.

Bellini, S., Peters, J., Benner, L., & Hopf, A. (2007). A meta-analysis of school-based social skills interventions for children with autism spectrum disorders. *Remedial and Special Education, 28*(3), 153-162.

Berkeley, S. L., Zittel, L. L., Pitney, L. V., & Nichols, S. E. (2001). Locomotor and object control skills of children diagnosed with autism. *Adapted Physical Activity Quarterly, 18*(4), 405-416.

Center for Disease Control and Prevention (CDC). (2011).

Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., et al. (2010). Randomized, controlled trial of an intervention for infants with autism: The Early Start Denver Model. *Pediatrics, 125*(1), 17-23.

Fombonne, E. (2009). A Wrinkle in Time: From early signs to a diagnosis of autism. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(5), 463-464.

Frankel, F., Myatt, R., Sugar, C., Whitham, C., Gorospe, C. M., & Laugeson, E. (2010). A randomized controlled study of parent-assisted children's friendship training with children having autism spectrum disorders. *Journal of Autism and Developmental Disabilities, 40*(7), 827-842.

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(5), 693-705.

Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for improved validity. *Journal of Autism and Development Disorders, 37*(4), 613- 627.

Green, D., Baird, G., Barnett, A. L., Henderson, L., Huber, J., & Henderson, S. E. (2002). The severity and nature of motor impairment in asperger's syndrome: A comparison with specific developmental disorder of motor function. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 43*(5), 655-668.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., et al. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine and Child Neurology, 51*(4), 311-316.

Gresham, F., Sugai, G., & Horner, R. (2001). Interpreting outcomes of social skills training for students with high-incidence disabilities. *Exceptional Children, 67*(3), 331-344.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young children with autism: a randomized controlled intervention study. *Journal of Child Psychology and Psychiatry, 47*(6), 611-620.

Kasari, C., Freeman, S., Paperella, T., Wong, C., Kwon, S., & Gultrud, A. (2005). Early intervention of core deficits in autism. *Clinical Neuropsychiatry, 2*(6), 380-388.

Kasari, C., Gulsrud, A., Wong, C., Kwon, S., & Locke, J. (2010). Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *Journal of Autism and Development Disorders, 40*(9), 1045-1056.

Kasari, C., Locke, J., Gulsrud, A., & Rotheram-Fuller, E. (2010). Social networks and friendships at school: Comparing children with and without ASD. *Journal of Autism and Developmental Disorders*.

Kasari, C., Paparella, T., Freeman, S., & Jahromi, L. (2008). Language outcome in autism: Randomized comparison of joint attention and play interventions. *Journal of consulting and clinical psychology, 75*(1), 125-137.

Kelley, E., Naigles, L., & Fein, D. (2010). An in-depth examination of optimal outcome children with a history of autism spectrum disorders. *Research in Autism Spectrum Disorders, 4*, 526-538.

Laugeson, E., Frankel, F., Mogil, C., & Dillon, A. (2009). Parent-assisted social skills training to improve friendships in teens with autism spectrum disorders. *Journal of autism and developmental disorders, 29*, 596-606.

Lloyd, M., MacDonald, M., & Lord, C. (2011). The motor skills of toddlers with autism spectrum disorders. *Autism*, 1-18.

Lord, C. (2000). The Autism Diagnostic Observation Schedule- Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3).

Luyster, R., Gotham, K., Guthrie, W., Coffing, M., Petrak, R., Pierce, K., et al. (2009). The Autism Diagnostic Observational Schedule- Toddler module: A new module of a standardized diagnostic measure of autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*, 1305-1320.

Matson, J., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 418-425.

Matson, J., Mahan, S., Fodstad, J. C., Hess, J. A., & Neal, D. (2010). Motor skills abilities in toddlers with autistic disorder, pervasive developmental disorder-not otherwise specified, and atypical development *Research in Autism Spectrum Disorders, 4*, 444-449.

McConnell, S. (2002). Interventions to facilitate social interactions for young children with autism: Review of available research and recommendations for educational intervention and future research. *Journal of Autism and Developmental Disorders, 35*(5), 351-372.

Morin, B., & Reid, G. (1985). A quantitative and qualitative assessment of autistic individuals on selected motor tasks. *Adapted Physical Activity Quarterly, 2*(1), 43-55.

National Research Council (NRC). (2001).

Rogers, S., Hayden, D., Hepburn, S., Charlifue-Smith, R., Hall, T., & Hayes, A. (2006). Teaching young nonverbal children with autism useful speech: A pilot study of the denver modeland PROMPT interventions. *Journal of Autism and Development Disorders, 36*, 1007-1024.

Staples, K., & Reid, G. (2009). Fundamental movement skills and autism spectrum disorders.

Sutera, S., Pandey, J., Esser, E. L., & Rosenthal, M. A. (2007). Predictors of optimal outcome in toddlers diagnosed with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 98-107.

Teitelbaum, P., Teitelbaum, O., Nye, J., Fryman, J., & Maurer, R. G. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Psychology, 95*, 13982-13987.

Ulrich, D. (2000). *Test of Gross Motor Development* (2nd Edition ed.). Austin, Texas: Pro-Ed.

Wong, V. C. N., & Kwan, Q. K. (2010). Randomized controlled trial for early intervention for autism: A pilot study of the autism 1-2-3 Project. *Journal of Autism and Developmental Disorders, 40*, 677-688.