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Relations among motor, social, and cognitive skills in pre-kindergarten children with developmental disabilities

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ABSTRACT

Despite the comorbidity between motor difficulties and certain disabilities, limited research has examined links between early motor, cognitive, and social skills in preschool-aged children with developmental disabilities. The present study examined the relative contributions of gross motor and fine motor skills to the prediction of improvements in children's cognitive and social skills among 2,027 pre-kindergarten children with developmental disabilities, including specific learning disorder, speech/language impairment, intellectual disability, and autism spectrum disorder. Results indicated that for pre-kindergarten children with developmental disabilities, fine motor skills, but not gross motor skills, were predictive of improvements in cognitive and social skills, even after controlling for demographic information and initial skill levels. Moreover, depending on the type of developmental disability, the pattern of prediction of gross motor and fine motor skills to improvements in children's cognitive and social skills differed. Implications are discussed.

1. Introduction

Children require the coordination of many different skills to be successful in school. Physical, cognitive, and social skills have all been highlighted as critical components of school readiness (Diamond, 2010; Duncan et al., 2007; Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010). In particular, early motor performance has been recognized as an important contributing factor for both cognitive and social functioning (Cameron et al., 2012; Cummins, Piek, & Dyck, 2005; Davis, Pitchford, & Limback, 2011; Kim et al., 2015; Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Piek, Baynam, & Barrett, 2006; Piek, Bradbury, Elsley, & Tate, 2008a). Motor development may act as a "control parameter" where certain motor abilities are necessary for the acquisition or practice of other developmental functions, including cognitive and social development (Bushnell & Boudreau, 1993; Campos et al., 2000). In other words, motor abilities, such as crawling or walking, may afford a child the opportunity to explore his or her environment more and do so in novel ways, thus, increasing his or her cognitive and social skills. On the other hand, delayed or deviant motor development in the early years of life is considered to be a precursor to developmental language and learning problems (Sala, Shulman, Kennedy, Grant, & Chu, 1999), problems with attention skills (Piek & Pitcher, 2004), and poor academic and social abilities (Losse et al., 1991; Piek et al., 2008a, 2010).

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Children with developmental disabilities are of particular interest in the study of motor skills because some developmental disabilities, including specific learning disorder (SLD), intellectual disability (ID), Autism Spectrum Disorder (ASD), and language disorders, may have a shared etiology, and poor motor skills have been implicated as one of the shared factors (Diamond, 2000; Dziuk et al., 2007; Martin, Piek, Baynam, Levy, & Hay, 2010). Children who have fine or gross motor impairments often exhibit cognitive delays and learning difficulties; similarly, children with cognitive disorders and intellectual disabilities are more inclined to experience motor problems (Diamond, 2000; Hartman, Houwen, Scherder, & Visscher, 2010). In addition, children with language disorders, as well as children with ASD often show problems with motor functioning (Diamond, 2000) and social skills (Dziuk et al., 2007; Hellendoorn et al., 2015).

Difficulties in motor functioning often provide valuable insights into developmental disorders and can also serve as indicators or markers for deficits in brain systems that are involved in cognition and social functioning (Dziuk et al., 2007). Despite the comorbidity between motor difficulties and certain developmental disabilities, limited research has examined links between early motor, cognitive, and social skills in preschool-aged children with developmental disabilities. Further, although some common traits underlie most developmental disabilities, young children with developmental disabilities are a heterogeneous group; hence, it is difficult to generalize patterns of findings given that these children exhibit various characteristics related to their developmental disorders. The purpose of the present study is to investigate differences in the pattern of prediction between motor skills and improvements over time in cognitive and social skills in an ethnically-diverse sample of preschool children with specific types of developmental disabilities, including SLD, speech/language impairment (SLI), ID, and ASD.

1.1. Links between motor, cognitive, and social skills

Research has established a clear link between motor, cognitive, and social skills. Studies show that gross motor skills, which use larger muscles, such as the legs and trunk, and are involved in activities like running, throwing, and catching, have been linked to children's cognitive functioning (Bushnell & Boudreau, 1993; Piek et al., 2006; Piek, Dawson, Smith, & Gasson, 2008b; Westendorp, Hartman, Houwen, Smith, & Visscher, 2011), as well as social functioning (Piek et al., 2006). Poor gross motor coordination has been linked to risk of lowered self-worth (Piek et al., 2006), poor attention and working memory (Niederer et al., 2011), as well as lower perceived scholastic ability (Piek et al., 2006) and higher probability of low academic achievement (Lopes, Santos, Pereira, & Lopes, 2013).

Recently, fine motor skills – which involve smaller muscles such as the hands and fingers, and are involved in activities like eating with utensils, finger-painting, cutting with scissors, and writing – were found to be more strongly related to some cognitive and social skills, as compared to gross motor skills, in typically-developing young children. For example, Grissmer et al. (2010) found evidence suggesting that early fine motor skills in kindergarten, rather than gross motor skills, were strongly and consistently associated with later school achievement. Additionally, Davis et al. (2011) examined the interrelations between cognitive and motor skills in children ages 4–11 years old and found that the association between cognitive and motor domains was largely due to fine motor control and visual processing, as opposed to more gross motor functioning, such as body coordination or strength and agility. Although research has examined gross motor and fine motor skills separately, very few studies have included both types of motor skills when examining associations with cognitive and social skills, specifically in children with developmental disabilities. It is unclear how gross motor and fine motor skills may relate to cognitive and social skills for preschool children with developmental disabilities, and specifically those with SLD, ID, SLI, or ASD. Therefore, we include measures of both gross motor and fine motor skills in our study to examine their relative contributions to improvements in cognitive and social skills across a preschool year in an ethnically-diverse group of children with developmental disabilities.

Several explanations are provided for the co-occurrence of motor, cognitive, and social skills. First, neurobiological evidence offers support for specific relations between cognitive and motor development. Motor development, especially the development of fine motor skills, requires neural networks and pathways that substantially overlap with those that underlie cognitive development (Floyer-Lea & Matthews, 2004; Pangelinan et al., 2011; Staines, Padilla, & Knight, 2002). For instance, tasks that activate the prefrontal cortex (PFC), an area of the brain associated with general cognitive ability, also activate areas of the brain, including the cerebellum and basal ganglia, necessary for motor learning (Diamond, 2000). Motor and social skills are connected at the neurophysiological level, as well. The PFC and the amygdala have a reciprocal connection and are both highly involved in aspects of social behavior and motor planning and execution (Bar-Haim & Bart, 2006). This close interrelation of motor, cognitive, and social development is also seen when looking at functional neuroimages of children with developmental disorders, including children with ASD (Davis, Pass, Finch, Dean, & Woodcock, 2009; Piek & Dyck, 2004). Structural abnormalities are found in brain regions that mediate the neural circuits involved in cognitive and motor performance, including the cerebellum and the PFC, suggesting that the neuroanatomical areas are interconnected, and that dysfunction in one region of the brain system may affect the other (Carper & Courchesne, 2000; Diamond, 2000; Dziuk et al., 2007).

Second, automaticity theory provides additional support for the connections between motor, cognitive, and social skills. The ability to perform a motor task accurately without exerting one's full attention allows for attentional resources to become available, making simultaneous performance of a second attention-demanding task easier (Floyer-Lea & Matthews, 2004; Huang & Mercer, 2001). Motor, cognitive, and social skills compete for the limited amount of attentional resources that are available. In early childhood classrooms, automaticity of motor skills is important because children often encounter situations where they need to simultaneously perform two tasks involving both motor and cognitive components (Cameron et al., 2012). For instance, children may need to pick up small items as they count them, while at the same time interact with adults and peers. In addition, the development of social skills involves learning complex motor sequences (Dziuk et al., 2007). Children who are able to automatize basic motor movements may benefit from having more attentional resources available to learn complex cognitive and social skills (Berger, 2010), whereas children who have not yet automatized these motor skills may need to exert more effort and attention to carry out the motor demands, thus, impeding their learning of more complex concepts (Lawrence et al., 2002).

Third, the theory of embodied cognition proposes that cognition emerges as we use our motor skills to interact with the environment (Thelen, 2000). In other words, cognition, as well as social development, is a complex, multifaceted embodied construct that develops as the child interacts with his or her surroundings (Campos et al., 2000; Hellendoorn et al., 2015; Thelen, 2000). The study of locomotion in infants provides evidence of the interrelation between these developmental domains. When infants are first beginning to move, they are not only increasing their motor skills but are also "learning to learn," by adapting to novel situations and finding solutions to maneuver around (Adolph, 2008). In addition, locomotor experiences impact social development by profoundly affecting the number of opportunities for social interaction, as well as changing attachment relationships and attentiveness (Campos et al., 2000). Hellendoorn et al. (2015) examined fine motor functioning in relation to visuospatial cognition, object and spatial exploration, social orientation, and language in preschool children with ASD, as compared to children with other developmental disabilities. Findings indicate that fine motor functioning aids preschool students in interacting with both the physical and social environment and improves visuospatial cognition, which in turn increases language development (Hellendoorn et al., 2015). Their results are in line with the theory of embodied cognition—that motor skills may constrain as well as facilitate the development of other skills (Thelen, 2000). To further explore this theory in the current study, we examine the relative contribution of both fine and gross motor skills to improvements in cognitive and social skills across a preschool year in children with developmental disabilities, as well as investigate potential differences in these associations for children with four specific developmental disabilities, SLD, SLI, ID, and ASD.

1.2. Types of developmental disabilities

Developmental disabilities share the essential feature of a predominant delay or disturbance in the acquisition of cognitive, motor, language, and/or social skills that have a significant and continuing impact on the development of a child (Shevell, Majnemer, Platt, Webster, & Birnbaum, 2004). Despite sharing certain features, children with developmental disabilities are a heterogeneous group and present different combinations of symptoms, which in turn suggests that associations between fine and gross motor skills and their cognitive and social skills may be different for different disabilities. In the present study, we examine four different developmental disabilities that, in addition to their unique symptoms, share the characteristic of motor difficulties (Diamond, 2000; Dziuk et al., 2007; Leary & Hill, 1996; Martin et al., 2010). These disabilities include specific learning disorder (SLD), speech/language impairment (SLI), intellectual disabilities (ID), and autism spectrum disorder (ASD), and are briefly described below. We recognize that many of the symptoms underlying each of these disabilities are not unique to one specific disability. For instance, ID and ASD covary at very high rates (Wilkins & Matson, 2009). For this study, we focus on the school system's exceptionality category, which are mutually exclusive, as this has implications for policy and classroom practices.

Children with specific learning disorder (SLD) have deficits in one or more academic areas, such as reading, mathematics, or writing in the context of otherwise typical cognitive functioning (American Psychiatric Association, 2013) and tend to exhibit worse gross motor skills, as compared to their typically-developing peers. Moreover, poor motor abilities have been linked to poor academic abilities in children with learning disabilities (Simons et al., 2008; Westendorp et al., 2011; Zhang, 2001).

Children with speech/language impairments (SLI) have deficits in the broader language system that interfere with communication, as well as in the production of speech sound, fluency, or voice that interfere with their ability to communicate successfully in the educational environment (State Board of Education Rule 6A-6.03012, Florida Administrative Code [F.A.C]). Substantial comorbidity exists between Specific Language Impairment, a type of speech/language impairment in which there are delays in the mastery of language skills, and a broad range of motor problems (Hill, 2001), including fine motor, motor coordination, and gross motor tasks, which may be due to the close association between motor and language development (Noterdaeme, Mildenberger, Minow, & Amorosa, 2002; Powell & Bishop, 1992).

Intellectual disability (ID), previously termed mental retardation (American Psychiatric Association, 2000), is a heterogeneous condition that has an onset before 18 years of age and is defined by significant impairments in cognitive capacity and adaptive functioning (American Psychiatric Association, 2013; Schalock et al., 2010). Children with ID are also often characterized by limited motor functioning (Pratt & Greydanus, 2007), including weaker gross motor (Westendorp et al., 2011) and fine motor skills (Wuang, Wang, Huang, & Su, 2008).

Autism spectrum disorders (ASD) are a group of lifelong, neurodevelopmental disorders characterized by differing severities of deficits in social interaction and communication across multiple contexts, as well as the presence of repetitive, stereotype behaviors and restricted interests (American Psychiatric Association, 2013). Overall, children with autism often exhibit atypical motor behaviors and have significant problems with basic motor control, including poor fine motor and gross motor skills (Bhat, Landa, & Cole, 2011; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Green et al., 2009; Hellendoorn et al., 2015), which may be markers for later communication and social delays (Libertus, Sheperd, Ross, & Landa, 2014).

1.3. Limitations of current literature

Although there has been an increase in research concerning motor, cognitive, and social skills, research focusing on connections among these three areas of development is limited in several ways. First, promising research has focused on improving fine motor skills as an avenue to improve academic achievement among typically developing peers (Grissmer et al., 2013). If the present study were to show that these associations also exist among students with developmental disabilities, then we may be able to identify new strategies to help children with developmental disabilities in school. Second, studies tend to focus on either general motor skills, fine motor skills, or gross motor skills when examining associations with children outcomes, such as cognition, academic achievement and social skills (Lopes et al., 2013; Piek et al., 2008a, 2010; Westendorp et al., 2011). However, fine and gross motor skills do not develop in isolation; thus, it is important to examine how fine motor and gross motor skills differentially contribute to the prediction of later cognitive and social skills. Third, little is known about how fine motor skills may relate to children's social skills, especially amongst children with poorer fine motor skills. Fourth, most of our current knowledge about links between motor skills and other domains of development comes from research on typically developing children (Cameron et al., 2012; Carlson, Rowe, & Curby, 2013; Dinehart & Manfra, 2013; Grissmer et al., 2010; Kim et al., 2015) or children with a diagnosis of Developmental Coordination Disorder (DCD; American Psychiatric Association, 2013) (Dewey, Kaplan, Crawford, & Wilson, 2002; Piek et al., 2006; Skinner & Piek, 2001), and less is known about children with other types of disabilities. Finally, very few studies examine differences in the pattern of associations between gross and fine motor skills and cognitive and social skills in preschool children with differing disability types. Certain preschool special education classrooms tend to combine children with various disabilities in the same classrooms ("non-categorical early childhood"; Individuals with Disabilities Education Improvement Act [IDEIA], 2004). It can be useful for teachers and other practitioners to have knowledge of how motor skills may differentially be helpful for the improvement of children's cognitive and social skills, depending on the type of disability.

1.4. Study objectives and research questions

In the present study, we examined associations among motor, social, and cognitive skills in a large and ethnically-diverse sample of preschool children attending public school pre-kindergarten (pre-K) programs for children with disabilities. In addition, we investigate potential differences in associations among these skills in four different disability groups: SLD, SLI, ID and ASD, because of the comorbidity between these disability types and motor problems. Specifically, we addressed the following research questions: (1) What is the relative contribution of fine and gross motor skills to improvements over time in preschool children's cognitive and social skills? (2) Are there differences in these patterns of associations depending on disability category?

2. Method

2.1. Participants

The participants were 2,029 ethnically-diverse children across four yearly cohorts who received pre-kindergarten special education services within a large, metropolitan public school system. The public school system was participating in a large-scale, county-wide, university-community collaborative evaluation of early childhood programs and services, and thus, represents a pre-K special education subsample of the larger project (Winsler et al., 2008, 2012).

Children between the ages of 3 and 5 who were significantly delayed (2 standard deviations below the mean) in the developmental domains of motor, social/emotional, language, cognitive, and/or adaptive skills qualified for special education services during pre-K and were temporarily labeled by the public schools as having a 'developmental delay.' At kindergarten entry, children who continued to be eligible to receive special education services were assessed and assigned a primary exceptionality – a more specific disability diagnosis – by the schools. These specific disabilities included, but were not limited to, autism, deafness, deaf-blindness, emotional disturbance, orthopedic impairment, hearing impairment, and speech and language impairment (Individuals with Disabilities Education Improvement Act [IDEIA], 2004). Because specific diagnoses (other than developmental delay) were not provided until kindergarten entry, in the current study, which took place in the USA, preschool children's specific disability category was defined by their primary exceptionality provided at kindergarten entry, which was obtained through administrative school records. This study examined four common disability groups identified by their primary exceptionality: specific learning disorder (SLD; $n = 898$); speech/language impairment (SLI; $n = 192$); intellectual disability (ID; $n = 509$); and autism spectrum disorder (ASD; $n = 430$). Demographic information for the full sample and each of the disability groups is presented in Table 1.

In this study, children were given the diagnosis of SLD if they had a disorder in one or more of the basic psychological processes involved in understanding or in using language, that may manifest itself as dyslexia, dyscalculia, dyspraxia, or dysgraphia; however, SLD does not include learning problems that are primarily due to visual, hearing, motor, intellectual, or

Table 1
Descriptive statistics for predictor and outcome variables for full sample and each disability category.

Variable		Child Age	Gender	Boys	Girls	FRL	Ethnicity	White/Other	Hispanic/ Latino	African American	T1 Fine Motor	T1 Gross Motor	T1 Cognitive	T2 Cognitive	T1 Social	T2 Social
Full Sample (*N* = 2029)	*N*	1793	2014	1524	490	1947	2012	242	1348	422	1359	884	1335	1234	1511	1369
	Missing	11.60%	0.70%			4.00%	0.80%				33.00%	56.40%	34.20%	39.20%	25.50%	32.50%
	M	4.61				0.67					17.27	18.35	28.84	35.39	60.53	66.83
	SD	0.33				0.47					4.35	4.79	8.21	9.4	16.97	17.3
	Range	3.31–5.70	0–1			0–1					7.5–29	9.0–32.0	14–55.5	14–55.5	4–108	0–107
Intellectual Disability (*N* = 509)	*N*	450	506	344	162	495	505	51	294	160	284	214	284	231	406	334
	Missing	11.60%	0.60%			2.80%	0.80%				44.20%	58.00%	44.20%	54.60%	20.20%	34.40%
	M	4.5				0.72					30.66	33.99	25.74	31.68	58.55	64.4
	SD	0.31				0.45					7.73	9.38	7.78	9.36	16.82	16.94
	Range	3.38–5.70	0–1			0–1					18–54	18–54	14–54.5	15.5–55.5	4–104	12–105
Speech/Language Impairment (*N* = 192)	*N*	167	188	135	53	186	188	30	127	31	145	75	147	137	142	135
	Missing	13.00%	2.10%			3.10%	2.10%				24.50%	60.90%	23.40%	28.60%	26.00%	29.70%
	M	4.59	0.28			0.62					39.67	39.15	33.64	41.02	71.37	79.59
	SD	0.34	0.45			0.49					8.52	11.06	8	8.53	15.64	16.22
	Range	3.31–5.50	0–1			0–1					22–55	18–54	15.5–54.5	14–55.5	31–108	17–105
Specific Learning Disorder (*N* = 898)	*N*	803	894	679	215	848	894	92	637	165	720	445	722	686	643	598
	Missing	10.60%	0.40%			5.60%	0.40%				19.80%	50.40%	19.60%	23.60%	28.40%	33.40%
	M	4.67	0.24			0.72					35.89	38.75	29.54	36.15	65.05	71.16
	SD	0.32	0.43			0.45					7.94	8.73	7.36	8.41	14.65	14.02
	Range	3.41–5.58	0–1			0–1					18–56.5	18–55	14–55.5	14–55.5	10–108	23–107
Autism Spectrum Disorder (*N* = 430)	*N*	373	426	366	60	418	425	69	290	66	188	138	182	180	320	302
	Missing	13.30%	0.90%			2.80%	1.20%				56.30%	67.90%	57.70%	58.10%	25.60%	29.80%
	M	4.65	0.14			0.54					31.11	33.2	27.03	32.95	49.15	55.25
	SD	0.34	0.34			0.5					9.09	8.84	9.78	10.92	15.32	16.84
	Range	3.55–5.70	0–1			0–1					18–55	18–51.5	14–54.5	14–55.5	9.0–94	0–106

Note. Full sample includes all four disability categories of intellectual disability, speech/language impairment, specific learning disorder, and autism spectrum disorder; child age is provided in years; FRL = free/reduced lunch status (0 = no; 1 = yes); T1 = Time 1; T2 = Time 2.

emotional/behavioral disability, limited English proficiency, or other environmental/contextual factors (State Board of Education Rule 6A-6.03018, F.A.C.). Specifically, the following criteria are used to determine eligibility for SLD: (1) does not adequately achieve or make adequate progress in the areas of language, reading, or mathematics for their chronological age, despite appropriate instruction; and (2) failure to achieve or progress is not primarily due to other disabilities (i.e., intellectual, emotional, visual, hearing, or motor disability), cultural or environmental factors, or limited English proficiency (State Board of Education Rule 6A-6.03018, F.A.C.).

Children were given a diagnosis of SLI if they had either impairment in speech or language or both. Speech impairments are disorders of the production of speech sound, fluency, or voice that interfere with a child's ability to communicate or perform effectively in the educational environment; in contrast, language impairments are disorders of the broader language system that interfere with communication (both receptive and expressive) and a child's functioning in school (State Board of Education Rule 6A-6.03012 and 6A-6.030121, F.A.C.). Although these two impairments have differing etiology and may manifest different symptomology, in the current study, as is done in many school districts, these impairments were not distinguished (State Board of Education Rule 6A-6.03012, F.A.C.). In the current Diagnostic and Statistical Manual of Mental Disorder-5th edition (DSM-V; American Psychiatric Association, 2013), SLI falls under the broader category of Communication Disorders; however, we use the term SLI based on the exceptionality status given by the school district at the time of the study.

Children were given a diagnosis of ID by the school system if they met the following criteria: (1) more than two standard deviations below the mean in terms of intellectual functioning and adaptive functioning; (2) level of academic performance on a standardized test is consistent with their level of intellectual functioning; and (3) identified developmental, familial, medical, and environmental factors that impact student functioning outside of the school environment (State Board of Education Rule 6A-6.03011, F.A.C.). Finally, children were given a diagnosis of ASD by the schools if they exhibited all of the following: (1) uneven developmental profile as evidenced by inconsistencies across developmental domains of language, social interaction, adaptive behavior, or cognitive skills; (2) deficits in social interaction and communication skills across multiple contexts; and (3) the presence of repetitive, stereotype behaviors and restricted interests (American Psychiatric Association, 2013; State Board of Education Rule 6A-6.03023 and 6A-6.0331, F.A.C.).

2.2. Pre-kindergarten special education program

Children in this study attended a state-funded, public school pre-kindergarten special education program for children with disabilities. The pre-kindergarten program serves children ages three to five years old in 204 classrooms in 105 schools across the school district and adopts the HighScope Curriculum, a research-based curriculum that emphasizes adult–child interactions and a carefully structured learning environment, where teachers and children work together to shape the educational experience (High/Scope Educational Research Foundation, 2015). In general, children participate in a wide-range of educational activities during the school day, including reciting nursery rhymes, engaging in social play, developing literacy skills through listening to stories, block play, art, music, as well as working on the specific skills in the Individual Educational Plan (IEP), which identifies delayed areas and skills for each individual child. Children in these programs are also eligible for speech and/or language therapy, as well as orientation and mobility services for those who qualify after an evaluation by certified specialists.

There are 12 program models available for pre-kindergarten children with disabilities that range from most restrictive (i.e., individual care given in the child's home or in a medical facility) to least restrictive (i.e., walk-in therapy for 0.5 h sessions in a small group of 3–4 children for support services). Typically, children attend full—(5.5 h each day) or half-day (2.5 h each day) programs, depending on what is most appropriate to meet their needs, five days a week. Children with various mild disabilities are usually placed in regular pre-kindergarten classrooms (19 typically-developing children and one child with disability) or Head Start classrooms (16–20 students) with the certified special education teacher visiting monthly to assist the teacher with adaptations and strategies. The above two types of programs were likely not represented in our sample, which focused on children who received some kind of more intense early childhood special education, and because children in Head Start programs were not included in this project due to a separate funding stream and different school readiness assessments used in those programs. Reverse mainstream classrooms (8–10 children with varying disabilities and 2–4 role model children) for children who can benefit from typically-developing peers but need a smaller class setting, were a common classroom model.

Children with various moderate disabilities attend the inclusion program, with about 8–10 children with disabilities and 8–10 role models (i.e., typically-developing children) for a total of 16–20 children, with one certified special education teacher and a paraprofessional. There are special programs for children with autism spectrum disorder (ASD): (1) a half-day program for children for whom social skills and language development are the primary focus—this program has four children with ASD and eight typically-developing children, with one certified special education teacher, and two paraprofessionals; and (2) a separate class for ASD for children who need a highly structured setting with 1:1 instruction—this program has approximately 8–10 children with ASD, with one certified teacher and two paraprofessionals. There are also special programs for children with significant intellectual disabilities (6–8 children with ID and one certified teacher and a paraprofessional) or speech/language impairments (half-day program with 10 children with SLI and 2–4 role model children, with one certified speech/language pathologist and a paraprofessional). We do not have data on which children attended which type of early intervention classrooms.

2.3. Procedures and measures

The public school pre-K program for children with disabilities was participating with the larger, county-wide, multi-agency, school readiness assessment program, which involved parents and teachers receiving the results of their child's school readiness assessments (Winsler et al., 2008, 2012). Parental consent was handled within the agency/public school system, and IRB/ethics approval for the assessments and for the secure and confidential administrative data sharing agreement was obtained through both the public school system's review procedure and the participating university IRBs. Children were individually assessed by their pre-kindergarten teachers in their motor and cognitive skills twice yearly, near the beginning of the 4-year-old pre-kindergarten academic year (Time 1: September–October) and at the end of the academic year (Time 2: April–May). Pre-kindergarten teachers also reported on children's social skills twice during the school year around the same time periods.

2.3.1. Learning accomplishment profile-diagnostic

To evaluate motor and cognitive performance, children were assessed directly by their pre-kindergarten teachers using the Learning Accomplishment Profile-Diagnostic (LAP-D; Nehring, Nehring, Bruni, & Randolph, 1992). The LAP-D, a comprehensive, norm-referenced, standardized assessment in which children are individually asked to perform simple actions, is used to assess children's cognitive, language, and gross and fine motor skills, as well as determine instructional and developmental milestones for children ages 36 to 72 months (Lidz, 2003). The three major developmental domains assessed were: Cognitive (57 items; raw score ranges from 0 to 57) which includes matching and counting subscales; Fine Motor (59 items; raw score ranges from 0 to 59), which includes manipulation and writing subscales; and Gross Motor (57 items; raw score ranges from 0 to 57), which includes body movement and object movement subscales. Language (53 items; raw score ranges from 0 to 53), which includes naming and comprehension subscales, was examined as a possible covariate in our models.

Raw scores for these subscales are used in the analyses due to our emphasis on change over time. Example cognitive items include "matches pictures of like animals" and "counts blocks to 10." Example fine motor items include "copies circle" and "laces through holes in outline of picture on lacing card." Example gross motor items include "balances on 1 foot for 8 seconds" and "catches bean bag with hands." Example language items include "names 18 pictures of common objects" and "points to 6 body parts upon request." Teachers individually administered the LAP-D assessments to the children in pre-kindergarten special education after completing an extensive, multi-day training conducted by personnel from a local university and the publisher of the instrument. Administration was in either Spanish or English, depending on which language the bilingual teacher believed was the child's strongest language.

The community's multi-agency task force selected the LAP-D assessment for several reasons: (1) the LAP-D assessment was compatible with the state's Early Learning Performance Standards (Florida Partnership for School Readiness, 2003); (2) the LAP-D assesses the developmental domains that were of particular interest, including cognitive, social, language, and motor skills; (3) the LAP-D was available in both English and Spanish; (4) the LAP-D was designed for both typically-developing and atypically-developing children and can be used to assist in the identification of children with disabilities (Hardin, Peisner-Feinberg, & Weeks, 2005); and finally, (5) the LAP-D has been shown to have good reliability and validity with the norming sample.

Specifically, the LAP-D was standardized using a sample of typically-developing preschoolers ($N = 792$), and internal consistency for the LAP-D during standardization was reported to be high in magnitude, ranging from $\alpha = 0.76–0.92$ (Nehring et al., 1992). Convergent validity was established during the standardization process by administering several other established instruments, including Developmental Indicators for the Assessment of Learning, Third Education (DIAL-3; Mardell-Czudnowski & Goldenberg, 1998) and Woodcock–Johnson Psycho-educational Battery-Revised (WJ-R; Woodcock & Johnson, 1989). Correlations with domains in these instruments and the LAP-D were significant and moderately high in magnitude, ranging from $r = 0.68–0.80$ (Nehring et al., 1992). The LAP-D has also shown good internal consistency reliability, with alphas above 0.90, within this community's ethnically and linguistically diverse sample (Winsler et al., 2008).

2.3.2. Devereux early childhood assessment

Teachers reported on children's social skills using the Devereux Early Childhood Assessment (DECA; LeBuffe & Naglieri, 1999). The DECA yields a Total Protective Factors (TPF) score, comprised of items from three subscales: Initiative (e.g., "choose to do a task that was challenging"), Self-Control (e.g., "handle frustration well"), and Attachment (e.g., "respond positively to adult comforting when upset"). Responses range from zero (*Never*) to four (*Very Frequently*), and TPF scores range from 0 to 108, with larger scores indicating more social protective factors.

The DECA was standardized using a sampling of typically-developing preschool children ($N = 2{,}000$) who closely represented the U.S. population on various demographic characteristics (LeBuffe & Naglieri, 1999). Internal reliability coefficients were all above 0.71, and many were above 0.90. The DECA is able to accurately discriminate between preschoolers with and without identified socio-emotional problems (LeBuffe & Naglieri, 1999). The internal consistency reliability for the DECA in the larger community-wide project was 0.94 for teacher report of Total Protective Factors and did not vary by the language form (English/Spanish) selected by the teacher (Winsler et al., 2008). Within the current sample of children with developmental disabilities, the internal consistency reliability for the teacher-reported DECA TPF was examined and found to be high (Cronbach's $\alpha = 0.94$). The DECA, thus, appears to show strong internal consistency reliability for teacher-report with this population of preschool children with developmental disabilities.

2.4. Analytic plan

Path analyses were performed in a Structural Equation Modeling (SEM) framework using Stata 12 (StataCorp, 2011). We chose to use the path modeling approach in SEM because, unlike multiple regression, it allows for the analysis of more complex models, such the inclusion of multiple dependent variables simultaneously, while also controlling for pre-score (i.e., Time 1 to Time 2) (Streiner, 2005). We were also able to account for missing data using the gold standard approach, Full-Information Maximum Likelihood, described below.

To examine the first research question, path analysis was used to evaluate associations between fine and gross motor skills at the beginning of pre-kindergarten (Time 1) and cognitive and social skills at the end of pre-kindergarten (Time 2), while controlling for the effects of gender, age, and free/reduced lunch status. Furthermore, similar to previous studies (e.g., Cameron et al., 2012), we included Time 1 cognitive and social skills in the same model to examine improvements in cognitive and social skills over the course of the pre-kindergarten year (see Fig. 1). Consistent with prior work (Morrissey, Hutchison, & Winsler, 2014), the current study uses free/reduced lunch status in the National School Lunch Program (NSLP) as a proxy for family income status. To qualify for free/reduced lunch, child's family must be at or below 185% of the Federal Poverty Level (FPL). At the end of data collection period for this study, the FPL was $20,650 for a family of four (U.S. Department of Health & Human Services, 2015); hence, the annual income threshold for a family of four was $38,203.

To examine the second research question, four separate path models were run for each of the disability categories (SLD, SLI, ID, and ASD). We chose to examine these associations separately for each disability category, as opposed to looking at how disability category moderates these associations. From the perspective of school practitioners, determining the importance of certain skills relative to another disability group does not inform best instructional approaches for how one would provide support in those skills for a specific group. For instance, if there are two students with different disabilities in the same classroom, and it turns out that fine motor skills seem to be important for later development for both disability groups, it does not matter that the strength of the relations between fine motor skills and later developmental skill was slightly weaker for one disability group compared to the other—what matters is that that fine motor skills are important to target for both students. Therefore, we examine differences in the pattern of associations between motor skills and children's cognitive and social skills for each disability category. All predictors were allowed to correlate, saturating the model and making the analyses comparable to a regression.

2.4.1. Missing data

Table 1 provides information on the sample, along with information on missing data. At first look, the missing data look challenging: Of the 2,029 participants, a total of 446 (22%) had complete data across all study outcome variables at both time points. However, the real estimation problems would come into play if data were missing at both time points and/or for most assessments. Herein, the missing data picture becomes much more manageable. Of those that had missing data at both time points, only 223 participants (11%) were missing data on motor and cognitive skills, followed

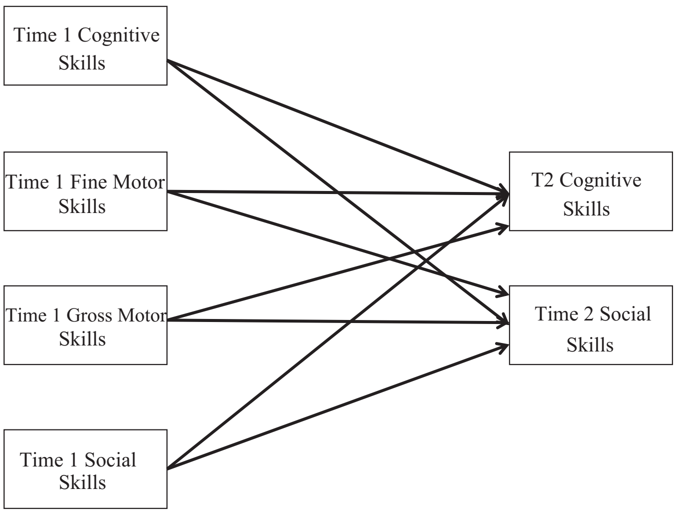

Fig. 1. Path model run for full sample, as well as for the four different disability categories separately, including intellectual disability, specific learning disorder, speech/language impairment, and autism spectrum disorder, to examine whether Time 1 fine motor and gross motor skills contribute to the prediction of children's Time 2 cognitive and social skills, after controlling for the effects of age, gender, ethnicity, free/reduced lunch status, and Time 1 cognitive and social skills. Demographic covariates are not shown in the model. All predictors were allowed to correlate, saturating the model and making the analyses comparable to a regression.

by those missing gross motor scores (183 participants; 9% of total), while another 101 participants (5% of total) were missing social skills scores. These patterns were similar when looking at the different disability groups separately. Thus, with the Time 1 and Time 2 associations in the model, we were able to account for longitudinal associations adequately and with correlations between variables within time, the model is able to account for when a given measure was missed at a given time.

Attrition, as well as study design (i.e., whether certain assessments were given for certain groups of students at certain time points), can lead to data that are not missing at random, and this can bias parameter estimates, especially when traditional methods, such as listwise deletion, are used (Enders, 2010). Of particular concern are selectivity effects, where missing data may be more likely in individuals with certain characteristics. Missing data analyses revealed that, in general, data were not missing systematically as a function of children's background information. The exception was for fine motor and cognitive skills at Time 2, where there were more missing data for older children, and for fine motor skills at Time 2 and social skills at Time 1, where missing data varied somewhat as a function of children's disability category. For fine motor skills at Time 2, there were more missing data for children with SLD; and for social skills at Time 1, there were more missing data for children with ID. Thus, we controlled for demographic characteristics and disability category (for full sample models) to account for these differences.

Missing data were handled by using Full-Information Maximum Likelihood (FIML). FIML is optimal for dealing with missing data because it uses all the available information to provide a more efficient estimate (Acock, 2005) and produces less-biased estimates than deletion methods (Enders, 2010; Worthke, 2000). Notably, to test for the effect that missing data may have had on the results, models were also run using listwise deletion. Results did not change significantly—in fact, the contributions of fine motor skills at Time 1 to children's social skills at Time 2 became stronger, though not significant, for children with SLI and ASD, which provides confidence in the reliability of our results. From here on, we present models in which FIML estimation was used.

3. Results

3.1. Preliminary analyses

Preliminary analyses were conducted to investigate the initial levels for fine and gross motor skills among children with different developmental disabilities, including SLD, ID, SLI, and ASD. Means and standard deviations for each variable of interest are provided for the full sample (includes all four disability groups) and for each disability group separately (Table 1). Children, on average, regardless of their specific disabilities, made gains of about 6–7 raw score points in their cognitive skills across the school year. Similarly, children made gains of about 6–8 raw score points in their social skills across the school year.

Pearson correlations between predictor and outcome variables for the full sample, as well as for each of the disability groups, are presented in Tables 2 and 3, respectively. The strength and direction of the associations between variables varied depending on the type of disability. Time 1 fine motor and gross motor skills were moderately related for the full sample ($r = 0.53$), as well as for each of the disability groups ($r = 0.41$–0.58). Similarly, Time 1 cognitive skills were correlated with both Time 1 fine motor ($r = 0.64$–0.73) and gross motor ($r = 0.33$–0.55) skills, but the associations were stronger for fine motor skills. The patterns were similar between Time 1 motor skills and Time 2 cognitive skills, but the associations were slightly weaker ($r = 0.53$–0.70) for fine motor; $r = 0.20$–0.51 for gross motor). Both Time 1 and Time 2 social skills were moderately positively related to all predictors and outcomes of interest ($r = 0.10$–0.37). As expected, Time 1 cognitive skills were a strong predictor of Time 2 cognitive skills ($r = 0.70$–0.83), and Time 1 social skills were a

Table 2
Correlations between predictor and outcome variables for full sample.

	Child Age	Gender	FRL	Ethnicity	T1 Fine Motor	T1 Gross Motor	T1 Cognitive	T2 Cognitive	T1 Social	T2 Social
Child Age	–									
Gender	−0.05[†]	–								
FRL	0.02	0.02	–							
Ethnicity	−0.01	0.01	0.30***	–						
T1 Fine Motor	0.28***	−0.02	−0.004	−0.08**	–					
T1 Gross Motor	0.19***	−0.15***	0.04	0.03	0.53***	–				
T1 Cognitive	0.24***	−0.08**	−0.12***	−0.14***	0.70***	0.46***	–			
T2 Cognitive	0.19***	−0.07**	−0.10***	−0.12***	0.61***	0.42***	0.77***	–		
T1 Social	0.02	0.09***	0.00	−0.01	0.28***	0.26***	0.23***	0.24***	–	
T2 Social	0.02	0.12***	−0.02	−0.02	0.32***	0.20***	0.28***	0.35***	0.72***	–

Note. Full sample includes all four disability categories of intellectual disability, speech/language impairment, specific learning disorder, and autism spectrum disorder; child age is provided in years; gender (0 = male; 1 = female); FRL = free/reduced lunch status (0 = no; 1 = yes); T1 = Time 1; T2 = Time 2.

[†] $p < 0.10$.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Table 3
Correlations between predictor and outcome variables for each disability category.

Top half shows correlations for speech/language impairment	Child Age	Gender	FRL	Ethnicity	T1 Fine Motor	T1 Gross Motor	T1 Cognitive	T2 Cognitive	T1 Social	T2 Social
Child Age	–	0.01	0.12	−0.004	0.43***	0.12	0.35***	0.24**	0.03	−0.02
Gender	−0.06	–	−0.04	0.04	0.03	−0.14	−0.13	−0.08	0.15	0.15
FRL	−0.01	−0.02	–	0.37***	0.01	0.06	−0.09	−0.13	−0.17*	−0.19*
Ethnicity	−0.02	0.00	0.27***	–	0.001	0.17	−0.09	−0.12	0.09	−0.04
T1 Fine Motor	0.37***	0.02	−0.02	−0.05	–	0.41***	0.68***	0.54***	0.24**	0.24*
T1 Gross Motor	0.31***	−0.21***	0.00	0.04	0.45***	–	0.33**	0.20	0.33*	0.13
T1 Cognitive	0.36***	−0.04	−0.08*	−0.10**	0.64***	0.37***	–	0.73***	0.14	0.26**
T2 Cognitive	0.32***	−0.06	−0.09*	−0.11**	0.53***	0.33***	0.70***	–	0.16	0.32**
T1 Social	0.10*	0.11**	−0.03	0.02	0.22***	0.17***	0.21***	0.16***	–	0.64***
T2 Social	0.11**	0.16***	−0.05	−0.01	0.26***	0.10	0.25***	0.27***	0.63***	–
Bottom half shows correlations for learning disability										

Top half shows correlations for intellectual disability	Child Age	Gender	FRL	Ethnicity	T1 Fine Motor	T1 Gross Motor	T1 Cognitive	T2 Cognitive	T1 Social	T2 Social
Child Age	–	0.06	0.06	0.03	−0.11	0	−0.15**	−0.23***	−0.16**	−0.20***
Gender	−0.07	–	0.07	0.04	−0.18**	−0.16*	−0.29***	−0.24***	0.03	0.02
FRL	0.04	−0.05	–	0.29***	0.004	0.1	−0.19*	−0.13	−0.02	−0.01
Ethnicity	0.04	−0.13**	0.32***	–	−0.06	0.11	−0.11	−0.1	−0.03	−0.001
T1 Fine Motor	0.17*	0.01	−0.1	−0.15*	–	0.58***	0.73***	0.70***	0.29***	0.25***
T1 Gross Motor	0.07	−0.01	−0.12	−0.11	0.51***	–	0.51***	0.50***	0.26***	0.25**
T1 Cognitive	0.13	0.03	−0.24**	−0.26***	0.73***	0.55***	–	0.83***	0.24***	0.25***
T2 Cognitive	0.13	−0.01	−0.19*	−0.18*	0.59***	0.51***	0.80***	–	0.27***	0.37***
T1 Social	0.06	−0.05	−0.07	−0.12*	0.22**	0.21*	0.15	0.33***	–	0.72***
T2 Social	0.08	−0.04	−0.06	−0.07	0.23*	0.2	0.18	0.37***	0.65***	–
Bottom half shows correlations for autism spectrum disorder										

Note. Child age is provided in years; gender (0 = male; 1 = female); FRL = free/reduced lunch status (0 = no; 1 = yes); T1 = Time 1; T2 = Time 2.
† $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

strong predictor of Time 2 social skills (r = 0.63–0.72). See Tables 2 and 3 for more specific correlations between variables for the full sample and for each of the different disability groups, respectively.

3.2. Interrelations among study variables

A path model was conducted to evaluate the relative contributions of both fine and gross motor skills at Time 1 to the prediction of improvements in cognitive and social skills in pre-kindergarten children with various developmental

Table 4
Path coefficients for gross and fine motor skills predicting improvements in cognitive and social skills for full sample.

Variables	T2 Cognitive Skills			T2 Social Skills		
	Standardized Coef	SE	*Z*	Standardized Coef	SE	*Z*
Full Sample that Includes All Disability Groups (n = 2029)						
Covariates						
Child Age	−0.02	0.02	−1.2	−0.04	0.02	−2.00*
Gender	−0.05	0.02	−2.52*	0.06	0.02	3.27***
Ethnicity	−0.03	0.02	−1.76†	0.005	0.02	0.22
FRL	−0.04	0.02	−1.98*	0.02	0.02	0.76
Predictors						
T1 Cognitive Skills	0.66	0.03	25.95***	0.11	0.04	3.07**
T1 Social Skills	0.07	0.02	2.65**	0.65	0.02	35.88***
T1 Fine Motor Skills	0.11	0.03	3.56***	0.1	0.04	2.44*
T1 Gross Motor Skills	0.04	0.03	1.44	−0.02	0.04	−0.64
R squared	0.64			0.55		
Overall R squared	0.81					

Note. Full sample includes all four disability categories of intellectual disability, speech/language impairment, specific learning disorder, and autism spectrum disorder; child age is provided in years; gender (0 = male; 1 = female); FRL = free/reduced lunch status (0 = no; 1 = yes); T1 = Time 1; T2 = Time 2.
† $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

disabilities, while controlling for the effects of gender, age, ethnicity, and free/reduced lunch status (see Fig. 1). The results of the analysis are presented in Table 4 for the full sample.

After accounting for their initial scores, fine motor skills significantly predicted *improvements* in children's cognitive skills and social skills. Gross motor skills, on the other hand, did not significantly contribute to improvement in either cognitive skills or social skills. The covariates and predictors together accounted for 64% of the variance of children's Time 2 cognitive skills and 55% of the variance of children's Time 2 social skills.

Table 5
Path coefficients for gross and fine motor skills predicting improvements in cognitive and social skills for each disability category.

Variables	T2 Cognitive Skills			T2 Social Skills		
	Standardized Coef	SE	*Z*	Standardized Coef	SE	*Z*
Intellectual Disability						
Covariates						
Child Age	−0.07	0.04	−1.80†	−0.06	0.04	−1.45
Gender	−0.05	0.04	−1.39	0.07	0.04	1.79†
Ethnicity	−0.04	0.04	−1.13	0.02	0.04	0.43
FRL	0.002	0.04	0.06	0.05	0.04	1.08
Predictors						
T1 Cognitive Skills	0.63	0.05	12.12***	0.15	0.08	1.93†
T1 Social Skills	0.08	0.05	1.63	0.66	0.04	17.01***
T1 Fine Motor Skills	0.20	0.05	3.69***	0.02	0.08	0.25
T1 Gross Motor Skills	0.03	0.05	0.62	−0.01	0.08	−0.19
R squared		0.76			0.55	
Overall *R* squared			0.87			
Speech/Language Impairment						
Covariates						
Child Age	−0.006	0.06	−0.09	−0.10	0.08	−1.16
Gender	−0.04	0.07	−0.58	0.10	0.08	1.31
Ethnicity	−0.06	0.07	−0.91	−0.08	0.09	−0.98
FRL	−0.02	0.07	−0.33	−0.02	0.08	−0.29
Predictors						
T1 Cognitive Skills	0.7	0.08	8.97***	0.28	0.11	2.57*
T1 Social Skills	0.05	0.08	0.71	0.54	0.07	7.49***
T1 Fine Motor Skills	0.02	0.11	0.15	−0.02	0.14	−0.18
T1 Gross Motor Skills	0.01	0.13	0.08	0.03	0.13	0.26
R squared		0.56			0.45	
Overall *R* squared			0.73			
Specific Learning Disorder						
Covariates						
Child Age	0.004	0.03	0.11	0.007	0.04	0.19
Gender	0.94	0.03	−1.52	0.11	0.03	3.45***
Ethnicity	−0.03	0.03	−1.18	−0.02	0.03	−0.57
FRL	−0.06	0.03	−1.98*	0.01	0.03	0.32
Predictors						
T1 Cognitive Skills	0.63	0.04	17.45***	0.05	0.05	1.07
T1 Social Skills	0.006	0.03	0.18	0.60	0.03	21.05***
T1 Fine Motor Skills	0.12	0.04	2.71**	0.10	0.05	1.92†
T1 Gross Motor Skills	0.01	0.05	0.22	−0.02	0.05	−0.39
R squared		0.53			0.44	
Overall *R* squared			0.73			
Autism Spectrum Disorder						
Covariates						
Child Age	0.04	0.05	0.9	−0.01	0.05	−0.22
Gender	−0.04	0.05	−0.8	−0.04	0.05	−0.84
Ethnicity	−0.004	0.05	−0.08	0.06	0.05	1.14
FRL	−0.04	0.05	−0.82	−0.01	0.05	−0.23
Predictors						
T1 Cognitive Skills	0.72	0.07	10.72***	0.15	0.12	1.23
T1 Social Skills	0.17	0.06	2.96**	0.59	0.05	12.38***
T1 Fine Motor Skills	−0.03	0.07	−0.4	0.07	0.12	0.58
T1 Gross Motor Skills	0.1	0.06	1.53	−0.002	0.1	−0.02
R squared		0.70			0.45	
Overall *R* squared			0.80			

Note. Child age is provided in years; gender (0 = male; 1 = female); FRL = free/reduced lunch status (0 = no; 1 = yes); T1 = Time 1; T2 = Time 2.
† $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

3.3. Interrelations by disability groups

Separate models were run for each of the four disability groups of intellectual disability, speech/language impairment, specific learning disorder, and autism spectrum disorder. Results from the path analyses (see Table 5, Fig. 1) revealed differences in the pattern of the relative contributions of gross and fine motor skills at Time 1 to improvements in cognitive and social skills over the course of the pre-kindergarten year, after accounting for the child's age, gender, ethnicity, and free/reduced lunch status. The findings are discussed separately for each disability group below[1].

3.3.1. Intellectual disability

After accounting for initial skill level, fine motor skills significantly and positively predicted improvements in cognitive skills, but not in social skills for children with intellectual disability. Gross motor skills, on the other hand, did not significantly contribute to improvements in either cognitive skills or social skills. The covariates and predictors together accounted for 76% of the variance of children's Time 2 cognitive skills and 55% of the variance of children's Time 2 social skills.

3.3.2. Speech/language impairment

Neither gross motor nor fine motor skills significantly predicted improvements in children's cognitive skills or social skills for children with speech/language impairment. The covariates and predictors together accounted for 56% of the variance of children's Time 2 cognitive skills and 45% of the variance of children's Time 2 social skills.

3.3.3. Specific learning disorder

For children with specific learning disorder, after accounting for initial skill level, fine motor skills significantly and positively predicted improvements in cognitive skills and marginally and positively predicted improvements in social skills. Gross motor skills, on the other hand, did not significantly contribute to improvements in either cognitive skills or social skills. The covariates and predictors together accounted for 53% of the variance of children's Time 2 cognitive skills and 44% of the variance of children's Time 2 social skills.

3.3.4. Autism spectrum disorder

For children with autism spectrum disorder, neither gross motor nor fine motor skills significantly predicted improvements in their cognitive skills or social skills. The covariates and predictors together accounted for 70% of the variance of children's Time 2 cognitive skills and 45% of the variance of children's Time 2 social skills.

To summarize our findings, for the overall sample of children with various disabilities, after accounting for demographic information, fine motor skills, but not gross motor skills, significantly predicted improvements in children's cognitive and social skills. When examining the disability groups separately, slightly different patterns of associations emerged. Fine motor skills were an important predictor of improvements in cognitive skills for children with intellectual disability and learning disability. However, for children with speech/language impairment and autism spectrum disorder, fine motor skills did not significantly predict improvements in their cognitive or social skills. Similar to the overall sample, for all four disability groups, gross motor skills were not a significant predictor of either cognitive or social skills.

4. Discussion

The current study sought to gain a better understanding of the associations between gross and fine motor skills and cognitive and social skills for preschool children with developmental disabilities. Specifically, we were interested in examining the relative contributions of fine and gross motor skills at the beginning of pre-kindergarten (Time 1) to the prediction of improvements in children's cognitive and social skills over the course of a pre-kindergarten year. In addition, we explored whether there were differences in the pattern of the contributions of gross and fine motor skills to improvements in children's cognitive and social skills for four separate disabilities, including intellectual disability (ID), speech/language impairment (SLI), specific learning disorder (SLD), and autism spectrum disorder (ASD).

Two main findings emerged from this study. First, for children with various developmental disabilities (full sample), fine motor skills, but not gross motor skills, appeared important for longitudinal improvements in children's cognitive and social skills, even after controlling for demographic information and initial skill levels. Second, the pattern of importance of gross motor and fine motor skills for improvements in children's cognitive and social skills differed somewhat depending on the type of disability of the child. For children with ID and SLD, fine motor skills were important for improvements in their cognitive skills over the course of a pre-kindergarten year. However, fine motor skills did not contribute to the prediction of improvements in cognitive or social skills for children with SLI and ASD. Furthermore, gross motor skills did not predict improvements in cognitive or social skills for any of the four disability groups.

[1] Previous studies have shown that language delays may be a prominent feature of certain disabilities, such as ASD (Hellendoorn et al., 2015); therefore, we conducted our path models, controlling for children's initial language skills. The results were essentially the same with or without the inclusion of language skills in the model; therefore, we presented the more parsimonious model that does not include language skills.

4.1. Fine motor skills predict improvements in cognitive and social skills

The current finding that fine motor skills, but not gross motor skills, contribute to cognitive and social skills in pre-kindergarten children with developmental disabilities corroborates evidence from recent research with typically-developing children (Davis et al., 2011; Grissmer et al., 2010). Predictive studies have found that motor and cognitive development are intricately linked and that motor opportunities that facilitate the interaction with the environment in early childhood are essential for cognitive growth (Campos et al., 2000). Thus, the fact that fine motor skills predicted improvements in children's cognitive skills is not surprising, given that children in early childhood programs, such as Head Start, spend a considerable portion of their day (37%) participating in some type of fine motor activity, and this increases to 46% in kindergarten classrooms (Marr, Cermak, Cohn, & Henderson, 2003). Because cognitive and fine motor milestones are interdependent, engaging each other toward higher-order functioning (Pagani & Messier, 2012), these fine motor activities may provide opportunities for children to expand their cognitive capacities through the challenges encountered while developing new motor skills. The association may be a result of the neural network that underlies both motor and cognitive processing, which links both areas during childhood (Davis et al., 2011; Diamond, 2000).

Additionally, our study found a link between fine motor skills and social skills, which supports previous studies that have indicated a significant association between social behavior and motor ability (Bar-Haim & Bart, 2006; Bart, Hajami, & Bar-Haim, 2007; Cummins et al., 2005; Piek et al., 2008b). For instance, Bar-Haim and Bart (2006) found that children with low motor abilities displayed lower frequencies of social play and higher frequencies of solitary play. In pre-kindergarten classrooms, children usually sit at tables in groups when working on fine motor activities, which can provide opportunities for social interaction; however, students who do not have adequate fine motor skills may avoid these activities, missing out on these social opportunities. Similarly, children with lower fine motor abilities may be unable to participate in many social activities due to their lack of ability to carry out the motor functions necessary for play, which can lead to social estrangement (Piek et al., 2008a). In fact, motor difficulties have been previously recognized as a contributing factor for poor social functioning in young children (Cummins et al., 2005; Piek et al., 2008b). Furthermore, evidence suggests that motor and social skills are interconnected at the neurophysiological level (Bar-Haim & Bart, 2006; Pagani & Messier, 2012). These transactions between brain structures may be an explanation as to why there were associations between motor and social skills in children with disabilities. A dysfunction in one area of the brain may have ramifications for multiple skills sets (Diamond, 2000). Similarly, strengthening one or more of these skills early on may have positive affects in related areas (Pangelinan et al., 2011).

Interestingly, we did not find a significant association between gross motor skills and cognitive or social skills. Our finding is in contrast to previous studies that have suggested that strong gross motor skills facilitate children's cognitive (Bushnell & Boudreau, 1993; Piek et al., 2008b) and social functioning (Cummins et al., 2005; Piek et al., 2008a). One study with pre-kindergarten children found that having motor difficulties was linked to higher levels of anxiety and depression (Piek et al., 2008a). Although the majority of studies examining gross motor skills included children without identified disabilities, some studies that have examined children with certain types of disabilities had similar findings. For instance, there was a negative association between gross motor skills and academic achievement for children with learning disabilities, such that children with poorer motor skills had a larger learning lag in mathematics and reading achievement (Westendorp et al., 2011). Reasons for the discrepancies in findings may be due to the outcomes that were examined and the sample of children. For example, the previously mentioned study by Piek et al. (2008a) used the Child Behavior Checklist for Ages 1.5–5 (CBCL; Achenbach & Rescorla, 2000) to examine internalizing and externalizing behaviors, as a measure of children's social–emotional functioning, in a small sample of children who were not identified as having disabilities. In contrast, the current study used the DECA, which measures socio-emotional protective factors in the areas of initiative, self-control, and attachment (LeBuffe & Naglieri, 1999), in a large, ethnically-diverse sample of pre-kindergarten children who have been diagnosed with various developmental disabilities. It is possible that gross motor skills relate to behavioral outcomes differently than socio-emotional protective factors and for children with certain developmental disabilities. More work is needed in this area. Another reason for the discrepancy may be due to the fact that previous studies have not examined relative contributions of fine and gross motor skills nor included both cognitive and social skills. Furthermore, these studies did not look children's fine or gross motor skills in relation to improvements over time in these outcomes (Bart et al., 2007; Piek et al., 2008b). Therefore, our findings provide a more complete and integrative picture of the predictive associations between fine and gross motor skills and improvements in social and cognitive skills across the pre-kindergarten year in children with developmental disabilities.

4.2. Differences exist in the pattern of associations by disability type

Differences in the pattern of associations between gross and fine motor skills and improvements in children's cognitive and social skills were observed, which is not all that surprising given that different characteristics and symptoms define each of the disabilities. Yet, there may be some distinct characteristics of these disabilities that may have contributed to the differing patterns of associations. For children with SLD and ID, fine motor skills, but not gross motor skills, contributed to improvements in cognitive skills, but not social skills, after accounting for demographic information and initial skill levels. Our findings are, in part, in line with previous studies that have shown that motor skills and cognitive skills are interrelated in children with SLD and ID (Houwen, van der Putten, & Vlaskamp, 2014; Westendorp et al., 2014). However, there is a relatively small body of literature on the motor functioning of children with SLD and ID, and the majority of these studies examine general motor functioning, without distinguishing between fine and gross motor skills, or only examine gross motor skills in relation to various outcomes in children with ID and SLD (Vuijk, Hartman, Scherder, & Visscher, 2010; Westendorp et al., 2011; Westendorp et al., 2014). Furthermore, unlike previous studies (Westendorp et al., 2011), we did not find evidence that gross motor skills predict improvements in cognitive or social skills in children with learning disabilities. This may be due to the fact that Westendorp et al. (2011) only examined gross motor skills in relation to academic achievement in a group of older children, ages 7–12 years old, whereas we included both fine motor and gross motor skills and examined younger children. Also, the strong association between fine motor skills and outcomes, as well as the overlap between fine motor and gross motor skills may have resulted in a lack of significance for gross motor skills in predicting improvements in cognitive and social skills. Nevertheless, our results provide some important practical implications for practitioners working with children with SLD or ID. First, practitioners should be aware of the specific associations between fine motor and cognitive skills. These specific associations may indicate that an early assessment of fine motor skills may be especially useful in identifying potential problems in later cognitive skills. Second, practitioners should consider emphasizing the practice of fine motor skills in order to facilitate children's cognitive skills.

Neither fine motor nor gross motor skills were significant predictors of improvements in cognitive or social skills for children with SLI or ASD. Research evidence suggests the co-occurrence of language and motor deficits (for review, see Hill, 2001). Specifically, children with language impairments, which are considered neurodevelopmental disorders, have been shown to have concomitant difficulties on motor control tasks (Nicolson & Fawcett, 1994). Children diagnosed with language impairments are those who fail to develop normal language but one cannot attribute this failure to mental or physical handicaps, hearing loss, emotional disorder, or environmental causes (Hill, 2001). Our null findings may be because our classification of SLI included not only children with the more serious language impairment but also those with speech impairments who only have difficulty with the fluent production of speech. Combining these two independent groups into one single, seemingly homogeneous group is misleading and may have contributed to the null findings.

In addition, the lack of significant findings between motor skills and improvements in cognitive of social skills for children with ASD is surprising, given that there is ample evidence of interrelations among motor, social, and cognitive skills in children with ASD (Fountain, Winter, & Bearman, 2012; Hellendoorn et al., 2015; see Jeste & Geschwind, 2014, for review). A recent study examined longitudinal relations between early fine motor functioning, visuospatial cognition, exploration, and language development measured around age two years through age three-and-a-half in children with ASD and children with developmental disabilities (Hellendoorn et al., 2015). The researchers found that fine motor functioning in children with ASD was related to visuospatial cognition, object exploration, and social orientation, as well as to language development, supporting the embodied cognition theory (Hellendoorn et al., 2015).

One possible reason for the contrasting findings is that our measure of motor skills was rather limited. Our measures of gross and fine motor skills assessed the presence or absence of a wide-range of motor behaviors, without distinguishing between specific types of fine or gross motor skills. On the other hand, the study conducted by Hellendoorn et al. (2015) used the Mullen Scales of Early Learning (MSEL; Mullen, 1995) and examined only fine motor object exploration but identified several components of fine motor functioning, including breadth (i.e., variability in children's object exploration skills), depth (i.e., integration of multimodal information and attentiveness), a combination of both breadth and depth, and atypical exploration behaviors. Another reason for differences in results is that we examined associations between both fine and gross motor skills and improvements over time in cognitive and social skills, whereas the Hellendoorn et al. (2015) study only included fine motor functioning and examined associations at a single time point. However, we recognize that children with ASD represent a heterogeneous group with varying developmental pathways that make is substantially difficult to diagnose, treat, and understand the specific mechanisms and pathways that underlie associated behavioral deficits (Fountain et al., 2012; Jeste & Geschwind, 2014).

Due to the exploratory nature of the current study, the heterogeneous nature of developmental disabilities, as well as significant overlaps in certain symptomologies, even when children are given specific diagnoses, it is difficult to speculate why certain patterns may have been found for specific disabilities but not for others. However, these differences in patterns of associations suggest a need for deeper understanding and exploration of the interrelatedness of these important domains, as well as more specificity in the types of skills that are related in children with different disability diagnoses.

5. Strengths and limitations

Overall, this study contributes to the current body of literature by providing much needed foundational research on the relative contributions of fine and gross motor skills to improvements in cognitive and social skills in young children with developmental disabilities. A major strength of the study is the size of our data set and diversity of our sample. Having data that included large numbers of ethnically-diverse children in each of the disability categories of interest allowed us to examine the differences in the pattern of contributions between gross and fine motor skills and cognitive and social skills in pre-kindergarten children with four different disability types. This can better inform educators and practitioners of the specific types of skills that may be important when working with diverse children with certain disabilities. Finally, we examined whether motor skills are important for *improvements* over time in cognitive and social skills. In other words, our results showed whether fine and gross motor skills contributed to the prediction of children's cognitive and social skills, over and above other well-known predictors of those outcomes, including demographic information, language skills, and initial cognitive and social skills.

As with all research, especially studies involving secondary data analysis on already existing agency data from a large-scale community project, there are some limitations worth mentioning. First, although longitudinal, path analysis cannot be used to establish causality of the associations found (Streiner, 2005). It may be that stronger motor skills lead to better cognitive and social skills or it may be the other way around, where stronger cognitive and social skills may lead to better motor skills or there may be bidirectional relations. Intervention studies have shown positive effects of occupational therapy and motor skill practice in increasing children's fine motor skills in pre-kindergarten and kindergarten children with motor delays (Bazyk et al., 2009; Dankert, Davies, & Gavin, 2003). Future studies should conduct randomized control trials that test the impact of increasing children's motor skills on their cognitive and social skills.

Second, we only examined motor skills in relation to cognitive and social skills; however, it is possible that there are other important skills that may explain improvements in cognitive and social skills. For example, language skills are known to correlate strongly with motor, cognitive, and social skills, both at the behavioral level (Iverson, 2010; Wellsby & Pexman, 2014) as well as at the neurological level (Leiner, Leiner, & Dow, 1991). Moreover, language delays may be prominent in certain disability types, such as ASD (Hellendoorn et al., 2015). Although we included children's initial language skills as a covariate, which did not change the results, we did not examine other related measures, such as IQ, which may serve as a causal source for both motor difficulties and poor cognitive and social outcomes. Thus, studies should assess additional characteristics and abilities that may be potentially related to motor, cognitive, and social skills.

Third, we recognize that there are large overlaps in the characteristics that define certain disabilities; and therefore, it may be difficult to parse effects for certain groups, as well as examine the additive effect of the behaviors and symptoms of related disorders, such as ASD and ID (Matson & Shoemaker, 2009). Relatedly, in the current study, children were given a diagnosis of SLI if they had either speech impairment or language impairment, which are two impairments that may have different etiologies. Nevertheless, SLI is a disability category that was given to children by the school system; and therefore, there was no way for us to separate out the groups. Examining associations among motor, cognitive, and social domains in children with speech impairment and language impairment separately is an important next step.

6. Implications and conclusion

Children with disabilities often have many disadvantages that have long-term consequences. Motor problems put an additional burden on the child and can significantly impact daily life and social interactions. Thus, determining the role that fine and gross motor skills may play in improvements in cognitive and social skills may help identify skills that can be intervened on early, which may reduce the burden of having motor difficulties, and may also help provide these children with an advantage later on and help them reach their full potential. Moreover, by identifying what the important skills are for improved cognitive and social performance for each of the disability categories, we can better target our intervention strategies depending on the diagnosis of the child.

The present study has some implications for those working with young children with developmental disabilities. First, educators and practitioners should be aware that children with developmental disabilities, despite potentially being grouped in the same classrooms, are a heterogeneous group in the skills that are important for school, including motor, cognitive, and social abilities. Moreover, there is also variability in the performance of and improvements in skills for children with the same diagnosis. Second, the results suggest that there may be other developmental skills besides just cognitive and social skills, such as motor skills, that may be important to focus on in pre-kindergarten for improvements in children's cognitive and social skills. Brain regions that are associated with more basic functions, including early motor skills, develop and mature first (Casey, Tottenham, Liston, & Durston, 2005); hence, early motor skills should be an important focus. Programs that address the whole child, by nurturing children's cognitive, social and physical/motor development, are the most successful at improving any single developmental domain, including academic development (Diamond, 2010). Children with various developmental disabilities, who are less prepared for school or show a delay in any or all developmental domains, may benefit from early intervention programs that emphasize not only children's cognitive and social development, but also include a strong motor component.

This study supports previous findings that motor skills may be important for other school-related skills, including cognitive and social skills, for children with certain developmental disabilities. More importantly, we found differences in the pattern of the contribution of fine motor skills to improvements in cognitive and social skills, depending on the specific type of developmental disability. The findings of this study highlight the importance of developing a better understanding of the interrelatedness of the specific readiness skills and how they may contribute to positive outcomes in children with disabilities, as well as pointing out that these associations may differ depending on the type of disability.

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