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Transdiagnostic Associations Between Motor and Language Abilities in Children with Developmental Disabilities

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Transdiagnostic Associations Between Motor and Language Abilities in Children with Developmental Disabilities

by

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Abstract

Theoretical perspectives and empirical evidence provide support for the relationship between motor and language abilities in typically and atypically developing children. Few studies have explored whether these associations persist across diagnosis, and whether there are profiles based on subtypes of motor and language abilities. The present study had the following aims: 1) is there an association between motor and language abilities across diagnosis; 2) are there associations between fine motor, gross motor, receptive language, and expressive language abilities across diagnosis; and 3) based on these associations between fine motor, gross motor, receptive language and expressive language, are there profiles of scores related to these abilities? Children with various developmental disabilities (e.g. autism spectrum disorder, language delay, cerebral palsy, Down syndrome, global developmental delay) were recruited at Renfrew Educational Services. Transdisciplinary teams administered the Carolina Curriculum for Infants, Toddlers, and Preschoolers with Special Needs, Second & Third Edition over a two-week period. Associations were demonstrated between overall motor and overall language abilities across diagnosis. Fine motor abilities were associated with and predicted receptive and expressive language. Gross motor abilities were associated with and predicted expressive language, but not receptive language. Four clusters of scores related to the subtypes of motor and language abilities emerged. Adopting a transdiagnostic approach provides a more realistic and comprehensive understanding of programming and intervention for children with developmental disabilities. Future studies are needed to ascertain whether these transdiagnostic associations persist over time.

Keywords: motor, language, children, associations, profiles, developmental disabilities, transdiagnostic

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Transdiagnostic Associations Between Motor and Language Abilities in Children with Developmental Disabilities

Historically, cognitive scientists viewed the mind as an abstract, symbolic information processor (Lenneberg, 1967), and cognition was not examined in the context of its relationship to the environment. Theorists that adopted this perspective emphasized the idea of modularity, which asserts that developmental domains are independent, domain-specific, encapsulated and hardwired (Fodor, 1983). Any concurrent advancements across developmental domains occur independently as a global maturational process, not because they are intrinsically linked (Bates et al., 1989; Bloom, 1993; Gesell, 1928; McGraw, 1943). However, this view of cognition was problematic, as explained by the symbol grounding problem. In Searle's (1980) Chinese room argument, an English speaker is in a closed room, and receives Chinese symbols through a hatch and returns other Chinese symbols following strict rules. However, the speaker does not know the meaning of any of the symbols. Therefore, if symbols are not linked to their referents, meaning can never be established. To ascertain the meaning of abstract symbols, they must be grounded in something other than more abstract symbols. This motivated the core tenet of embodied cognition: cognitive processes must be grounded in sensorimotor interactions with the environment (Iverson, 2010; Lakoff, 1987; Wilson, 2002). This theory posits that cognition is context-specific, modal, and dependent on other domains of development (Meteyard et al., 2012). The indexical hypothesis (IH), derived from embodied cognition, attempted to solve the symbol grounding problem by proposing that meaning is about real-world action rather than symbolic representations (Glenberg & Robertson, 1999). The IH asserts that the meaning of a situation is the set of actions, or affordances, available to an individual in that situation.

Therefore, instead of mapping arbitrary, abstract symbols to each other, cognition can be grounded in the affordances a certain action enables.

Embodied cognition falls on a continuum from abstract, symbolic, unembodied theories to strong versions of embodiment. In line with traditional perspectives of cognition, unembodied theories posit no role for sensorimotor information in cognition and suggest an arbitrary relationship between cognition and perception (Meteyard et al., 2012). Further along the embodiment continuum is secondary embodiment, which does not propose a hard boundary between cognition and sensorimotor information. Cognition is still abstract in nature and independent from sensorimotor information, but is grounded by non-arbitrary, associative connections with sensorimotor representations (Mahon & Caramazza, 2008). A weak theory of embodiment further advocates for strengthening the association between cognition and sensorimotor representations, proposing that cognition is at least partially constituted by sensorimotor information (Meteyard et al., 2012). When activated during cognition, sensorimotor information has a representational role rather than being secondary to abstract cognition as purported by secondary embodiment. Lastly, strong theories of embodiment assert that cognition is completely dependent on sensorimotor information. This view is supported by the perceptual symbol systems theory, which states that perceptual symbols are based in sensorimotor neural systems that are activated when perception occurs, and sensorimotor information is activated in all cognitive processes (Barsalou, 1999). Additionally, representations are formed through “full simulation”, which is when perceptions are recreated through activation in sensorimotor areas of the brain (Gallese & Lakoff, 2005).

The action-sentence compatibility effect (ACE), demonstrated in a study by Glenberg and Kaschak (2002), provides further support for strong embodiment. The ACE illustrates that motor systems are activated based on the actions referred to in a sentence. Undergraduate students determined whether a sentence was sensible by moving their hand to a button that was either closer to or farther away from their body (Glenberg & Kaschak, 2002). For the sentence “close the drawer”, the action performed by the participant was compatible if the hand moved away from the body because the hand typically moves away from the body when closing a drawer. On the other hand, responses toward the participant’s body were incompatible with “close the drawer”. Results revealed that response times for pressing the button were faster for action-compatible sentences than action-incompatible sentences, providing evidence in support of the idea that there is a relationship between perception and sensorimotor information. Other researchers found similar results, demonstrating the ACE (Borreggine & Kaschak, 2006; Zwaan & Taylor, 2006). However, recent evidence has emerged investigating the reliability and validity of the ACE. Papesh (2015) conducted extensions and replications of the ACE in eight experiments. Results revealed that the ACE was not demonstrated in a mouse-movement paradigm with new sentences, with the original sentences from the Glenberg and Kaschak (2002) study, or in a paradigm that closely matched the original study. Therefore, results of the ACE must be taken with caution as recent studies have failed to replicate it. The validity of strong embodiment in general is questionable as it cannot fully account for other factors that contribute to cognition such as abstract concepts and morphosyntactic information (Tirado et al., 2018).

Other theories such as functionalism (Penner-Wilger & Anderson, 2013) apply a developmental approach, postulating that the acquisition of motor skills enables children to engage in activities that support cognitive, academic, and language development (Suggate & Stoeger, 2017). Iverson (2010) argued that motor experiences during infancy transform children’s environment to prepare them for language acquisition and overall cognitive development. The attainment of motor skills during the first 18 months of life (e.g. posture, locomotion, grasping) provides infants with a broader set of opportunities for interacting with the world (Iverson, 2010). For instance, learning to point using gestural communication enables children to engage in social interactions and label objects by learning from their parents or caregivers (Carpenter et al., 1998). Moreover, Campos et al. (2000) proposed that when infants begin to crawl, there is a rapid change in the type of social signals they receive. Crawling infants typically encounter risky objects and contexts as they explore their surroundings, to which caregivers respond by utilizing their vocal communication to ensure their children's safety (Zumbahlen, 1997). Relatedly, walking allows infants to travel and frees the hands to grasp objects and learn their functional use (Walle & Campos, 2014). Fundamentally, advancements in motor abilities during infancy facilitate new opportunities for socio-communicative interactions, and thus accelerate language acquisition and development. Studies investigating the body-object interaction (BOI) effect, which is the ease with which a body can physically interact with a word's referent (Siakaluk, Pexman, Sears, et al., 2008), provide support for functionalism. High-BOI objects (e.g. mask, toothbrush) are easy to manipulate and interact with, and low-BOI objects (e.g. ship, elephant) are difficult to manipulate and interact with. Researchers found that response times to lexical information were faster and more accurate for high-BOI words than low-BOI words (Siakaluk, Pexman, Aguilera, et al., 2008). Furthermore, graspability, how easily a person can grasp an object with one hand, is also a predictor of lexical-semantic processing (Heard et al., 2019). The BOI effect provides support for functionalism because it demonstrates that increased interactions with objects within the environment facilitates language development.

Overall, theoretical standpoints such as embodied cognition and functionalism advocate for the connection between sensorimotor representations and cognition. In line with these theoretical perspectives, various researchers have specifically investigated the relationship between motor and language abilities. The following section will discuss behavioural evidence from longitudinal and cross-sectional studies corroborating the association between motor and language abilities in typically developing children.

Associations Between Motor and Language Abilities in Typically Developing Children

Various studies have demonstrated associations between oral motor skills and language (Alcock & Krawczyk, 2010; Nip et al., 2011), but empirical evidence has also revealed associations between fine motor abilities and language in typically developing children. In terms of correlational studies, researchers have demonstrated that pointers have larger vocabularies at 18 months compared to non-pointers (Moore et al., 2019). Moreover, at 3 years, children's fine motor abilities are positively correlated with language (Lekhal et al., 2014). Longitudinal studies of typically developing children have demonstrated similar associations between motor and language abilities. A study investigating a large epidemiological sample of Australian children showed that gesturing at 8 months contributed to a significant amount of variance in expressive vocabulary at 12 and 24 months (Bavin et al., 2008). Fine motor abilities at 3 months are associated with better expressive and receptive language at 4 and 10 years (Salavati et al., 2017). Robust links between fine motor skills and receptive vocabulary have been demonstrated from preschool to second grade in the US (Pagani et al., 2010). In a sample of children between 3 and 6 years, Dellatolas et al. (2003) found links between fine motor abilities and receptive and expressive vocabulary. Overall, results of both cross-sectional and longitudinal studies demonstrate that fine motor abilities such as gesture and pointing are associated with language in typically developing children. These findings provide support for theories of embodied cognition and functionalism, which emphasize the intrinsic relationship between motor and language development.

In addition to oral motor and fine motor abilities, associations between gross motor abilities such as walking and crawling, and language have been established. A cross-sectional study demonstrated positive correlations between sitting and receptive language at 10 months (Libertus & Violi, 2016). Longitudinally, walking experience at 10 months is a significant predictor of receptive and expressive language at 13.5 months (Walle & Campos, 2014). Other researchers have found opposite associations between gross motor abilities and language development, revealing positive predictions from early language skills at 3 years to later gross motor abilities at 5 years (Wang et al., 2014). Oudgenoeg-Paz et al. (2016) looked at a mediation model to study the longitudinal relations between walking, exploration, and linguistic skills, and found that exploration at 20 months mediated the effect of age of walking on language at 43 months. Consistent with embodied cognition and functionalism, the attainment of gross motor abilities such as crawling and walking alter the environmental experiences of children, paving the way for language and communicative development.

Associations Between Motor and Language Abilities in Atypically Developing Children

Researchers have proposed that because atypically developing children have impairments in one or more domains of development, they lack embodiment. For example, Eigsti (2013) explained that because children with ASD have motor deficits, these difficulties could potentially contribute to weakened embodied processing. Moreover, the ‘broken mirrors’ hypothesis by Ramachandran and Oberman (2006) asserts that children with ASD have impairments in their mirror neuron systems, resulting in a disruption of the connection between perception and action.

In contrast, evidence exists that demonstrates embodied processes persist in atypically developing children. A number of studies have investigated associations between motor and language abilities in children with developmental disabilities such as autism spectrum disorder (ASD; Bedford et al., 2016; LeBarton & Landa, 2019; Luyster et al., 2008), language delay (Chuang et al., 2011; Tsiouri & Greer, 2003), cerebral palsy (Choi, Park, Choi, et al., 2018; Lipscombe et al., 2016; Parkes et al., 2010), Down syndrome (Alcock, 2006; Yamauchi et al., 2019), and global developmental delay (Riou et al., 2009; Shevell et al., 2005). In children with ASD, gross motor abilities are a significant predictor of expressive and receptive language (Bedford et al., 2016). Children with language delay demonstrate greater impairments in gross and fine motor abilities compared to typically developing children (Chuang et al., 2011). Additionally, children with cerebral palsy with impairments in communication have co-occurring impairments in gross motor function (Parkes et al., 2010). In children with Down syndrome, acquisition of walking skills has a significant positive effect on language-social skills (Yamauchi et al., 2019). In children with global developmental delay, fine motor and expressive language scores correlate with one another (Riou et al., 2009). Together, these studies demonstrate that although children with developmental disabilities have impairments in one or more domains of development, associations between motor and language abilities persist..

A limited number of studies have investigated associations between motor and language abilities in samples of children with multiple developmental disabilities. However, a few studies demonstrated relationships between specific motor abilities (e.g. imitation of simple sounds, manual dexterity, ball skills) and language outcomes (Delehanty et al., 2018; Thurm et al., 2007; Vuijk et al., 2011). Other studies have investigated associations between broader fine and gross motor abilities and language. One study of preschoolers with developmental delay, speech/language delay and ASD found that gross motor abilities mediated the effect of age on receptive, expressive, and written language (MacDonald et al., 2017). Relationships have also been demonstrated between fine motor abilities and overall language in children with ASD and Down syndrome (Whitmore, 2015). The current study aims to extend these findings to explore the associations between both fine motor abilities and language and gross motor abilities and language in a sample of children with multiple developmental disabilities.

If relationships are revealed between motor and language abilities, we can then ask whether impairments in motor abilities co-occur with impairments in language abilities, or are there compensatory effects such that impairments in one domain result in advances in other domains? Therefore, another aim of this study is to investigate whether participants score either low or high on subtypes of motor and language abilities, or whether there is an inverse relationship between these abilities. To explore this aim, the present study will investigate whether certain profiles of scores on motor and language abilities emerge across diagnosis. A few studies have profiled children with a single developmental disability based on performance across several domains of development such as language, motor, cognitive, and academic functioning (Stone et al., 1999; Wiggins et al., 2017; Yang et al., 2016). Specific to motor and language abilities, one study discovered clusters of autistic children with either positive or negative relationships between nonverbal skills (e.g. fine motor skills) and verbal skills (e.g. receptive and expressive language) (Kim et al., 2016). However, this study only assessed fine motor, receptive language, and expressive language abilities in children with a single diagnosis. The present study aimed to form clusters of children with multiple developmental disabilities based on their fine motor, gross motor, receptive language, and expressive language abilities.

The Present Study

The present study investigated associations between motor and language abilities in a heterogeneous sample of children with multiple developmental disabilities such as ASD, language delay, cerebral palsy, Down syndrome, and global developmental delay. The study also aimed to ascertain the nature of the relationship between motor and language abilities in these children by investigating whether there are profiles of scores related to subtypes of motor and language abilities. There are three research questions: 1) is there an association between motor and language abilities across diagnosis; 2) are there associations between fine motor, gross motor, receptive language, and expressive language abilities across diagnosis; and 3) based on these associations between fine motor, gross motor, receptive language and expressive language, are there profiles of scores related to these abilities?

For the first research question, I hypothesized that an association will emerge between overall motor and overall language abilities, consistent with previous literature investigating these abilities in children with multiple developmental disabilities (MacDonald et al., 2017; Vuijk et al., 2011; Whitmore, 2015). For the second research question, I hypothesized that, consistent with previous literature investigating associations between motor and language abilities across diagnosis, both fine motor and gross motor abilities will be associated with expressive and receptive language (Delehanty et al., 2018; MacDonald et al., 2017; Thurm et al., 2007; Vuijk et al., 2011). Lastly, since the present study was the first to investigate profiles of scores on fine motor, gross motor, receptive language, and expressive language abilities in children with multiple developmental disabilities, I had no a priori hypothesis for the third research question.

Method

Participants

Participants were recruited at Renfrew Educational Services (RES), a not-for-profit society and registered charity that offers education programs for typically and atypically developing children, across five centres in Calgary, AB. The sample consisted of 52 children with an age range of 2.75 years to 11.33 years (*M* = 5.13 years, *SD* = 1.59 years), and there were 16 female and 36 male participants. Children were assessed from Spring 2018 to Winter 2019, and had primary diagnoses of language delay (*N* = 17), autism spectrum disorder (ASD; *N* = 20), cerebral palsy (*N* = 5), Down syndrome (*N* = 2), global developmental delay (*N* = 2), and a diagnosis categorized as other (*N* = 4). Several children in the sample had multiple diagnoses, and two children were missing a diagnosis.

Procedure

Ethics was obtained through the Conjoint Faculties Research Ethics Board at the University of Calgary. Informed consent was obtained from parents for their children and from staff at RES for use of their data. Five children were recruited from each classroom at a RES location by a transdisciplinary team consisting of two individuals. The team was a combination of teachers, therapists (e.g. psychologists, occupational therapists, speech-language pathologists), and child development facilitators. An assessment for each child was completed over a two-week period by the transdisciplinary team. Prior to testing, a consultation and observation phase took place, wherein the team decided on the child's developmental level for each skill area. Then, while in the classroom, one transdisciplinary team member participated in play-based interactions with the child, while the other member observed and coded the child's behaviour on the assessment. After completing the assessment, each transdisciplinary team member completed a feedback survey to evaluate the assessment and the transdisciplinary team experience. All data were anonymized, securely coded and shared between the two partnership institutions, the University of Calgary and RES.

Measures

Children were administered the Carolina Curriculum for Infants, Toddlers, and Preschoolers with Special Needs, Second & Third Edition (CC). Staff at RES combined the Carolina Curriculum for Infants and Toddlers with Special Needs, Third Edition (Johnson-Martin et al., 2004a), and the Carolina Curriculum for Preschoolers with Special Needs, Second Edition (Johnson-Martin et al., 2004b) into one assessment. The CC is an observational assessment tool designed for use with children who have mild to severe disabilities. This assessment aims to create a broader picture of children's abilities in a familiar and ecologically valid environment. Each item on the assessment is play-based and observational, so a direct link is facilitated between observation and intervention. It is designed to inform individualized program planning and aid in goal development and strategy implementation. The CC targets skills in three main domains: social-practical, cognitive, and motor. Due to participant and administrator burden, RES removed some of the skill sections from the original CC which contained 24 scales. The revised CC contains 10 scales: Self-Regulation and Responsibility, Interpersonal Skills, Functional Use of Objects & Symbolic Play, Problem-Solving/Reasoning, Verbal Comprehension, Conversation Skills, Imitation: Motor, Bilateral Skills, Upright: Posture & Locomotion, and Upright: Outdoor Play (see Appendix A). For the present study, only scales from the revised CC were analyzed. However, some participants were administered the original CC with 24 scales which contains some optional sections, resulting in some missing data.

Data Coding

The CC is not a standardized assessment, so a coding system was developed to quantify performance on the 10 scales. Each item on the CC corresponded with an age range (e.g. 24 to 30 months), reflecting their developmental age. Administrators indicated ‘+’ when a skill was mastered, ‘+/-’ when a skill was emerging, and ‘-’ when a skill was not achieved. Scoring began when the first ‘+’, ‘+/-’, or ‘-’ was recorded on the assessment. Children had to achieve ‘+’ in more than 50% of the items in an age range to be scored as having mastered the age range. Children had to achieve ‘+/-’ in at least 50% of the items in an age range to be scored as having emerging skills in the age range. Additionally, administrators wrote ‘A’ if the child could complete the item with physical assistance. ‘A’ and ‘A+’ were scored as ‘+’, ‘A+/-’ was scored as ‘+/-’, and ‘A-’ was scored as ‘-’. If the administrator left an item blank in the middle of scoring or wrote ‘NA’, it was scored as a ‘-’. If a child had more than 50% ‘-’ in an age range, it was not scored. Therefore, it was possible for a child to achieve no mastered or emerging age range in a scale. If possible, children achieved a maximum emerging age range and maximum mastered age range for each of the 10 CC scales. For the present study, only the mastered skills on the CC were analyzed, as the emerging skills were not well-defined and operationalized.

Data Analysis

All data analysis was completed in IBM SPSS Statistics 25.0 (IBM Corp., 2017) and figures were created in R (R Core Team, 2018). Prior to data analysis, the data was cleaned, and outliers defined as having a z-score of greater than 2.50 or less than -2.50 were removed from the dataset (Field, 2009). Descriptive statistics were computed such as demographics (e.g. gender, diagnosis, age). For the present study, scores on the 10 CC scales were presented for descriptive purposes, but only the motor and language scales were utilized in the statistical analyses. The median value was utilized for each age range (e.g. 24 to 30 months was coded as 27 months) to derive a continuous age equivalent score. A variable for overall motor abilities was derived by computing the average age equivalent score of the Imitation: Motor, Bilateral Skills, Upright: Posture & Locomotion, and Upright: Outdoor Play scales. A variable for fine motor abilities was derived by computing the average age equivalent score of the Imitation: Motor and Bilateral Skills scales, and a variable for gross motor abilities was derived by computing the average age equivalent score of the Upright: Posture & Locomotion and Upright: Outdoor Play scales. A variable for overall language abilities was derived by computing the average age equivalent score of the Verbal Comprehension and Conversation Skills scales. Receptive language was coded as the age equivalent score on the Verbal Comprehension scale, and expressive language was coded as the age equivalent score on the Conversation Skills scale.

Results

Transdiagnostic descriptive statistics across the 10 scales of the CC and demographic information is presented in *Table 1*. Descriptive statistics of the overall motor, overall language, fine motor, gross motor, receptive language, and expressive language subscales according to gender and diagnosis are presented in *Table 2*. Gender, diagnosis and chronological age were not significantly correlated to any of the overall motor, overall language, fine motor, gross motor, receptive language, and expressive language variables, so they were not controlled for in the analyses. Descriptive statistics are not presented for children with global developmental delay as the sample size was not large enough to compute means and standard deviations.

Table 1

Descriptive Statistics and Bivariate Correlations Among the 10 CC Scales

	N	*M*	*SD*	Range	1	2	3	4	5	6	7	8	9	10	11	12
1. Child gender	52			1-2												
2. Chronological age (months)	52	62.04	18.76	33-136	.052											
3. Child diagnosis	50	2.38	1.56	1-6	-.002	.238										
4. Self-Regulation and Responsibility	49	31.53	13.73	1.5-57.0	-.040	.026	-.277									
5. Interpersonal Skills	41	21.48	17.29	1.5-57.0	.351*	.032	-.297	.693**								
6. Functional Use of Objects & Symbolic Play	44	18.07	14.12	1.5-57.0	.293	-.085	-.320*	.741**	.847**							
7. Problem-Solving/Reasoning	45	24.43	12.89	4.5-57.0	.214	-.009	-.146	.703**	.795**	.819**						
8. Verbal Comprehension	43	28.08	15.46	1.5-57.0	.207	.164	-.357*	.698**	.728**	.609**	.582**					
9. Conversation Skills	44	18.75	13.06	1.5-57.0	.101	.111	-.092	.668**	.834**	.765**	.725**	.715**				
10. Imitation: Motor	43	29.48	19.78	1.5-57.0	.224	.005	-.090	.701**	.564**	.669**	.578**	.570**	.570**			
11. Bilateral Skills	50	26.73	12.92	1.5-57.0	.039	-.187	-.294*	.570**	.504**	.532**	.598**	.517**	.372*	.592**		
12. Upright: Posture & Locomotion	49	28.04	14.56	1.5-57.0	.040	-.173	-.407**	.436**	.205	.455**	.388*	.327*	.174	.601**	.649**	
13. Upright: Outdoor Play	50	32.58	11.25	13.5-51.0	.001	-.150	-.424**	.260	.124	.234	.233	.180	.129	.467**	.532**	.655**

Note. *N* = sample size; *M* = mean; *SD* = standard deviation. Child gender: 1 = male; 2 = female. Child diagnosis: 1 = language delay; 2 = autism spectrum disorder; 3 = cerebral palsy; 4 = Down syndrome; 5 = global developmental delay; 6 = other.

** $p < .01$; * $p < .05$.

Table 2

Descriptive Statistics According to Gender and Diagnosis

	Overall Motor		Overall Language		Fine Motor		Gross Motor		Receptive Language		Expressive Language	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gender												
Males	28.41	12.00	21.70	11.34	26.23	13.86	30.60	12.17	26.00	14.17	17.90	10.23
Females	29.04	13.57	25.50	18.65	29.80	15.94	29.86	12.63	32.88	17.74	17.75	15.66
Diagnosis												
Language delay	33.38	11.33	28.40	15.81	31.76	14.40	34.99	9.43	32.79	15.81	23.19	14.11
ASD	29.78	9.66	18.43	10.53	25.84	12.09	33.71	9.40	25.76	13.67	13.17	9.30
Cerebral palsy	14.33	8.56	25.80	15.35	17.25	16.53	11.40	3.45	26.10	15.17	19.13	7.18
Down syndrome	33.94	9.28	19.50	19.09	36.00	8.49	31.88	10.08	20.25	26.52	18.75	11.67
Other	15.75	15.09	16.75	7.28	16.50	17.30	18.00	15.05	21.00	2.12	16.00	9.53

Note. *M* = mean; *SD* = standard deviation; ASD = autism spectrum disorder.

Research Question 1: Is There an Association Between Overall Motor and Overall Language Abilities Across Diagnosis?

To investigate whether there was an association between overall motor and overall language abilities, a bivariate Pearson correlation was computed between these scores across the entire sample. Results presented in *Table 3* below demonstrate that overall motor and overall language scores were significantly correlated, with a large effect size, r (44) = .568, $p < .001$. This significant correlation was followed up with a linear regression, with overall motor abilities as the independent variable and overall language abilities as the dependent variable. Results presented in *Table 4* below reveal that overall motor abilities significantly predicted overall language abilities, F (1, 44) = 21.001, $p < .001$, $R^2 = .323$, Adjusted $R^2 = .308$. The association between overall motor and overall language abilities is visualized in *Figure 1*.

Table 3

Descriptive Statistics and Bivariate Correlations Among the CC Subscales

	N	*M*	*SD*	Range	1	2	3	4	5
1. Overall motor	51	28.61	12.38	4.5-49.5					
2. Overall language	47	22.91	13.99	1.5-51.0	.568**				
3. Fine motor	50	27.30	14.45	1.5-54.0	.934**	.671**			
4. Gross motor	51	30.37	12.19	4.5-51.0	.906**	.327*	.681**		
5. Receptive language	43	28.08	15.45	1.5-57.0	.513**	.943**	.612**	.279	
6. Expressive language	43	17.86	11.79	1.5-45.0	.503**	.913**	.585**	.316*	.699**

Note. *N* = sample size; *M* = mean; *SD* = standard deviation.

** $p < .01$; * $p < .05$.

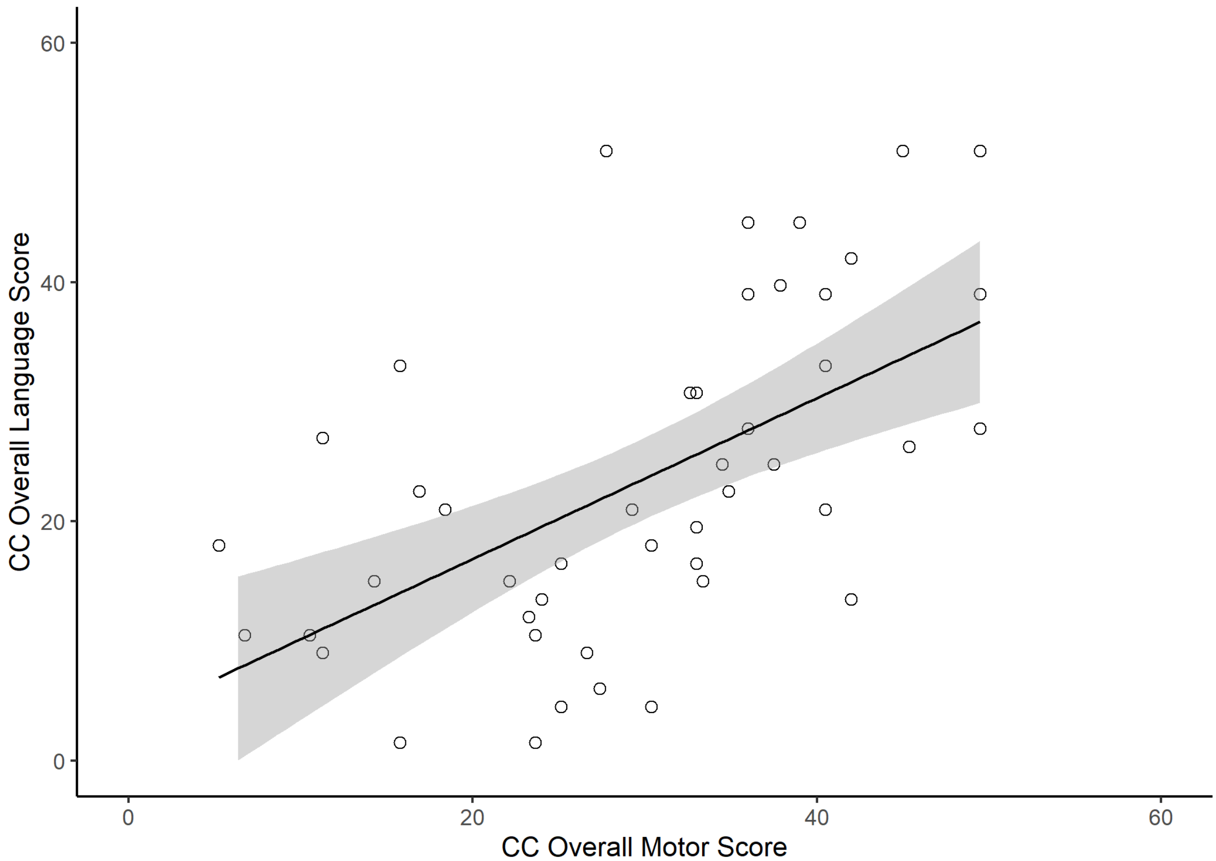
Table 4

Linear Regression Analyses Between the CC Subscales

Model	B	SE-B	Beta	t	95% CI		p
					LL	UL	
Overall motor and overall language	.672	.147	.568	4.583	.376	.967	< .001
Fine motor and receptive language	.666	.136	.612	4.888	.391	.942	< .001
Fine motor and expressive language	.487	.107	.585	4.565	.271	.702	< .001
Gross motor and expressive language	.324	.154	.316	2.109	.014	.635	.041

Figure 1

Scatterplot of Overall Motor Scores Versus Overall Language Scores



Note. Shaded area represents confidence intervals.

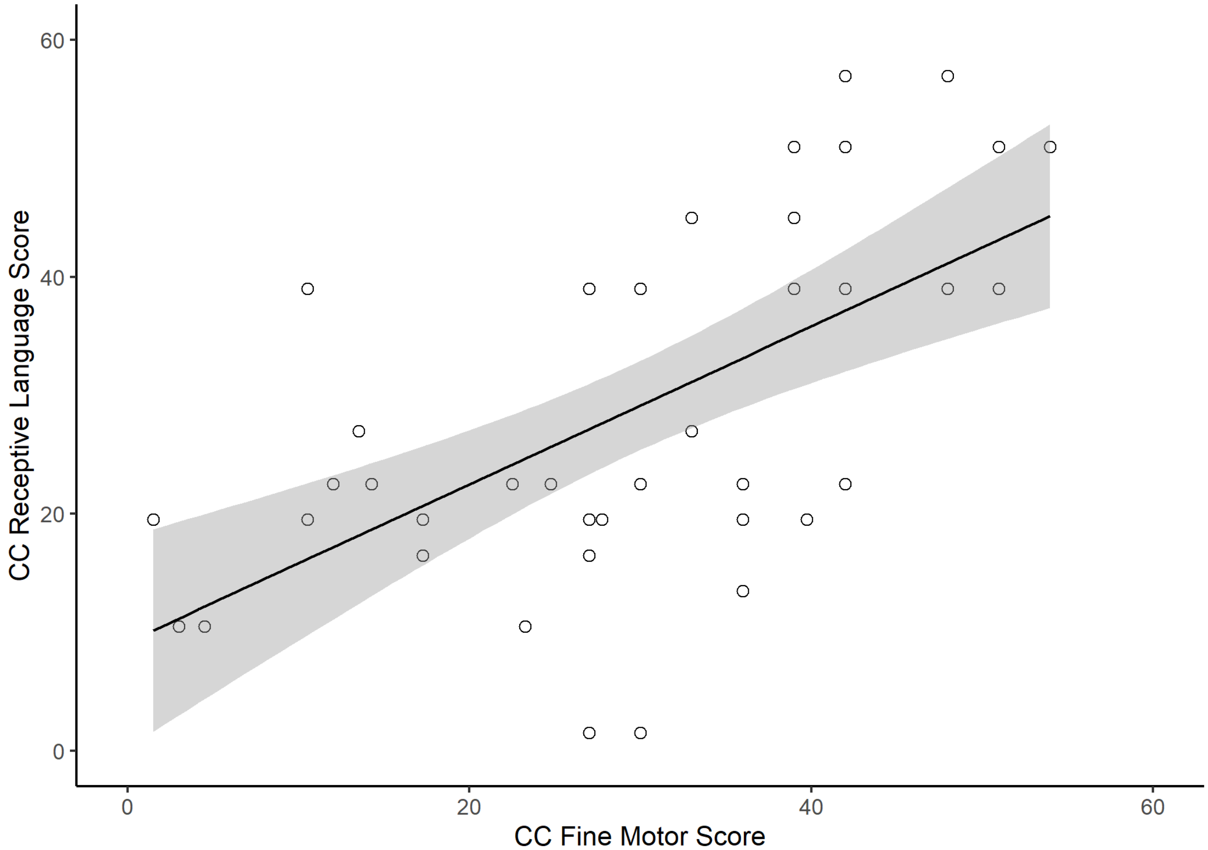
Research Question 2: Are There Associations Between Subtypes of Motor and Language Abilities Across Diagnosis?

To investigate whether there were associations between subscales on the CC, bivariate Pearson correlations were computed between scores on the fine motor, gross motor, receptive language, and expressive language variables across the entire sample. These correlations are displayed in *Table 3* above. Results revealed that there was a significant correlation between fine motor abilities and receptive language, r (40) = .612, p < .001, fine motor abilities and expressive language, r (40) = .585, p < .001, gross motor abilities and expressive language, r (40) = .316, p

= .041, but not gross motor abilities and receptive language, *r* (40) = .279, *p* = .073. The associations between fine motor abilities and receptive language and fine motor abilities and expressive language demonstrated large effect sizes, and the association between gross motor abilities and expressive language demonstrated a moderate effect size. Significant correlations were followed up with three linear regressions: 1) fine motor abilities as the independent variable and receptive language as the dependent variable; 2) fine motor abilities as the independent variable and expressive language as the dependent variable; and 3) gross motor abilities as the independent variable and expressive language as the dependent variable. Results of these regression analyses are presented in *Table 4* above. Fine motor abilities significantly predicted receptive language, F (1,40) = 23.891, p < .001, R^2 = .374, Adjusted R^2 = .358. Fine motor abilities also significantly predicted expressive language, F (1,40) = 20.842, p < .001, R^2 = .343, Adjusted R^2 = .326. Gross motor abilities significantly predicted expressive language, F (1,40) = 4.449, p = .041, R^2 = .100, Adjusted R^2 = .078. The associations between the subscales of the CC are visualized in *Figures 2, 3,* and *4.*

Figure 2

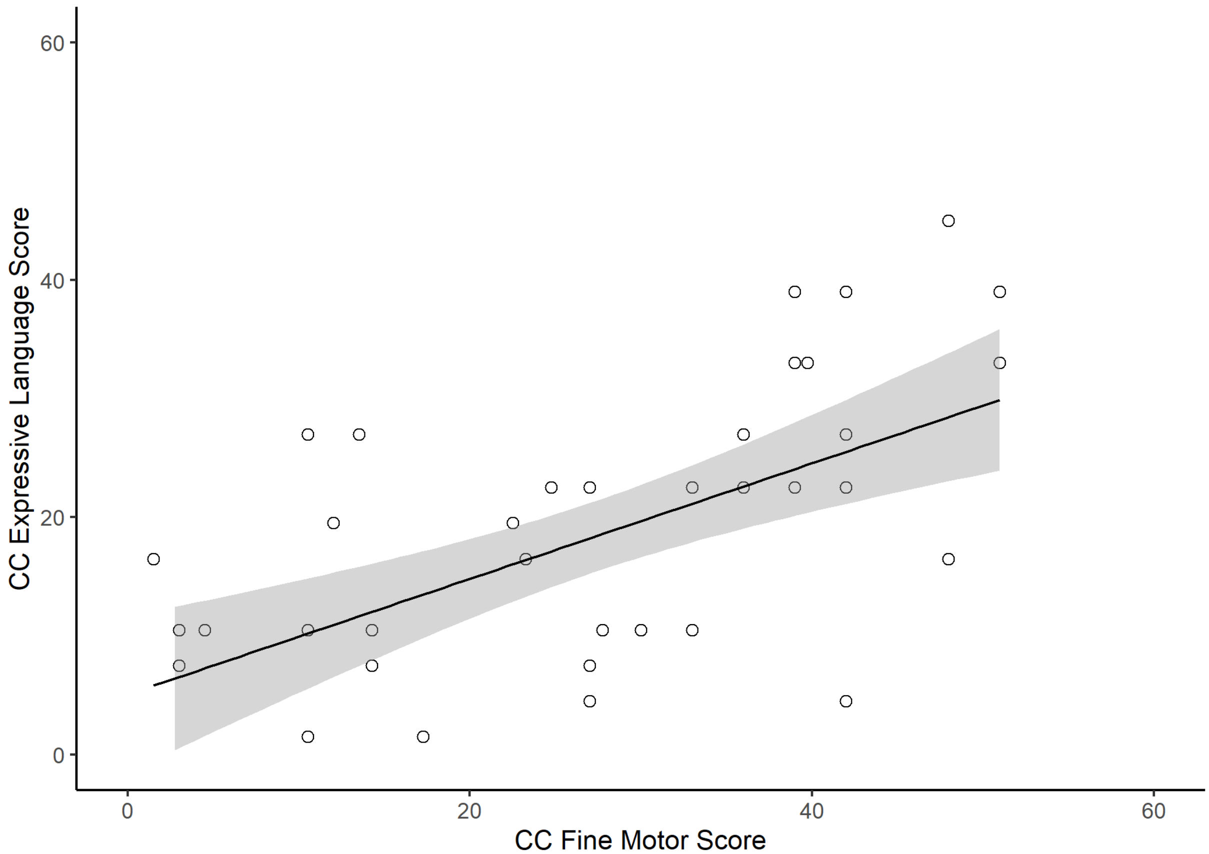
Scatterplot of Fine Motor Scores Versus Receptive Language Scores



Note. Shaded area represents confidence intervals.

Figure 3

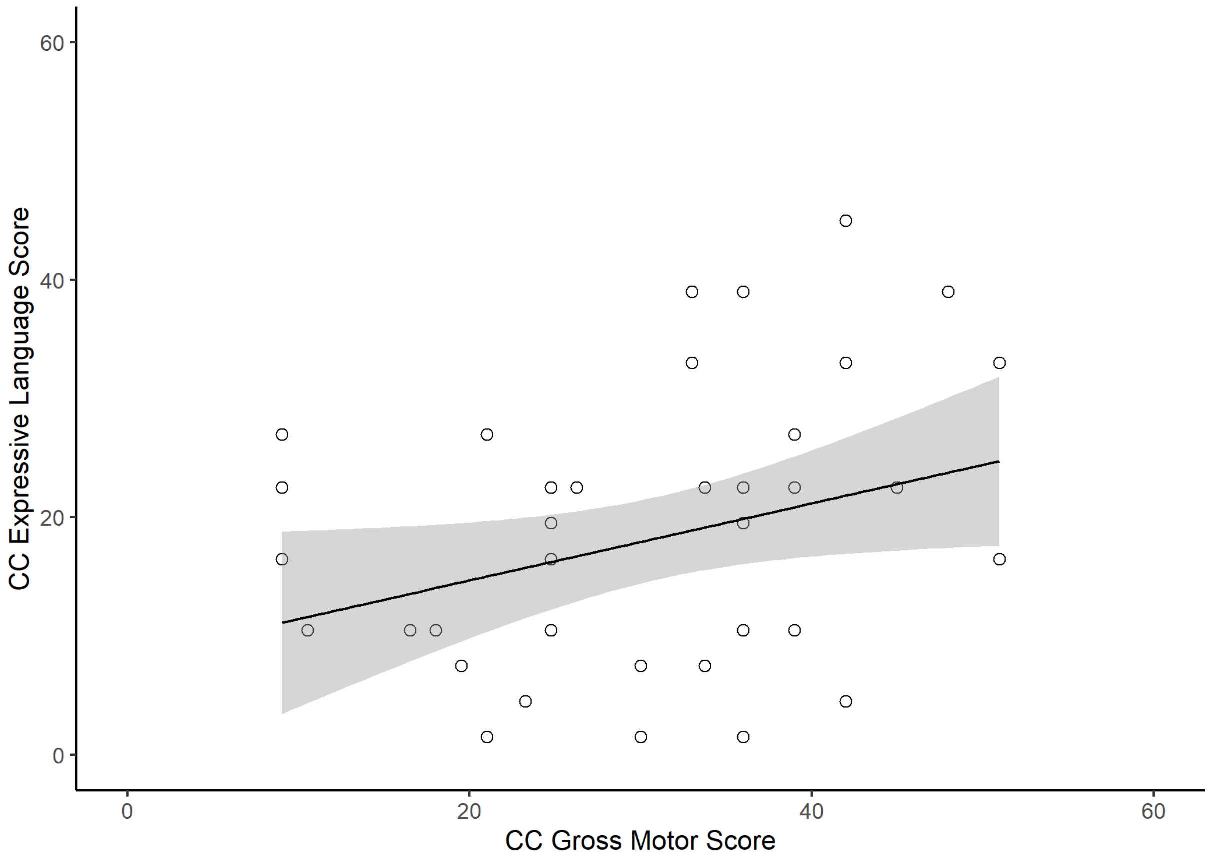
Scatterplot of Fine Motor Scores Versus Expressive Language Scores



Note. Shaded area represents confidence intervals.

Figure 4

Scatterplot of Gross Motor Scores Versus Expressive Language Scores



Note. Shaded area represents confidence intervals.

Research Question 3: Are There Profiles of Scores Related to the Subtypes of Motor and Language Abilities?

Fine motor, gross motor, receptive language, and expressive language scores were analyzed using a k-means cluster analysis to determine if there are profiles of scores related to these abilities. This analysis approach can identify from a relatively large sample a few subgroups of cases based on a small set of variables. This analysis is exploratory, so there is no need to specify a priori hypotheses, and several cluster solutions can be tested (Meyers et al., 2013). The k-means clustering method is iterative in that it reallocates cases to clusters throughout the analysis, thereby allowing homogeneous clusters to be formed that are comprised of the most similar cases (Dawes et al., 2008). It is also agglomerative in that cases are added to a cluster over the course of completing a phase in the analysis. In the classification phase, a set of *k* cases is identified, where *k* is the number of clusters specified prior to the analysis. These cases serve as seed points or initial cluster centers. Clusters are then built with a case at a time joining the cluster to which it is the most similar. This process continues until the change in distance between cases reaches its criterion threshold or reaches the maximum number of iterations specified beforehand, and the final cluster centers are obtained.

K-means clustering requires scores on all of the variables, so only 38 participants with scores on the fine motor, gross motor, receptive language, and expressive language subscales were clustered. Subscale scores were converted to z-scores, and the number of iterations was specified as 50 to ensure that the most optimal solution was obtained. Since this analysis is exploratory, two-cluster, three-cluster, and four-cluster solutions were tested, but only data on the four-cluster solution is presented as participants were most evenly distributed within each cluster in this solution. Convergence was reached in three iterations, and univariate ANOVAs indicated that the clustered groups differed significantly on all four variables (all *p*s < .001). The final cluster centers with the number of cases in each cluster are presented in *Table 5* below. The number of cases in each cluster ranged from 7 to 12, so the sample sizes were relatively equal. Participants in Cluster 1 had high fine (*M* = 36.41, *SD* = 6.80) and gross motor scores (*M* = 41.11, *SD* = 7.01), and average receptive (*M* = 30.41, *SD* = 9.72) and expressive language scores (*M* = 21.00, *SD* = 7.94). Approximately half of these participants had a diagnosis of ASD, and a third had a diagnosis of language delay. Participants in Cluster 2 had high fine motor (*M* = 44.57, *SD* = 5.32), gross motor (*M* = 38.25, *SD* = 5.83), receptive language (*M* = 50.14, *SD* = 6.41), and expressive language scores (*M* = 35.79, *SD* = 7.16). Over half of these participants had a diagnosis of language delay. Participants in Cluster 3 had average fine (*M* = 23.88, *SD* = 6.95) and gross motor scores (*M* = 30.88, *SD* = 6.20), and low receptive (M = 15.75, SD = 7.69) and expressive language scores (*M* = 10.50, *SD* = 6.40). Over half of these participants had a diagnosis of ASD, and a quarter had a diagnosis of language delay. Participants in Cluster 4 had low fine (*M* = 10.03, *SD* = 7.42) and gross motor scores (*M* = 15.84, *SD* = 6.15), and average receptive (*M* = 21.38, *SD* = 9.17) and expressive language scores (*M* = 17.63, *SD* = 7.64). Half of these participants had a diagnosis of cerebral palsy, and a quarter had a diagnosis of ASD. Scores on the fine motor, gross motor, receptive language, and expressive language variables according to cluster membership are visualized in *Figure 5*, and the diagnostic composition of each cluster is displayed in *Figure 6*.

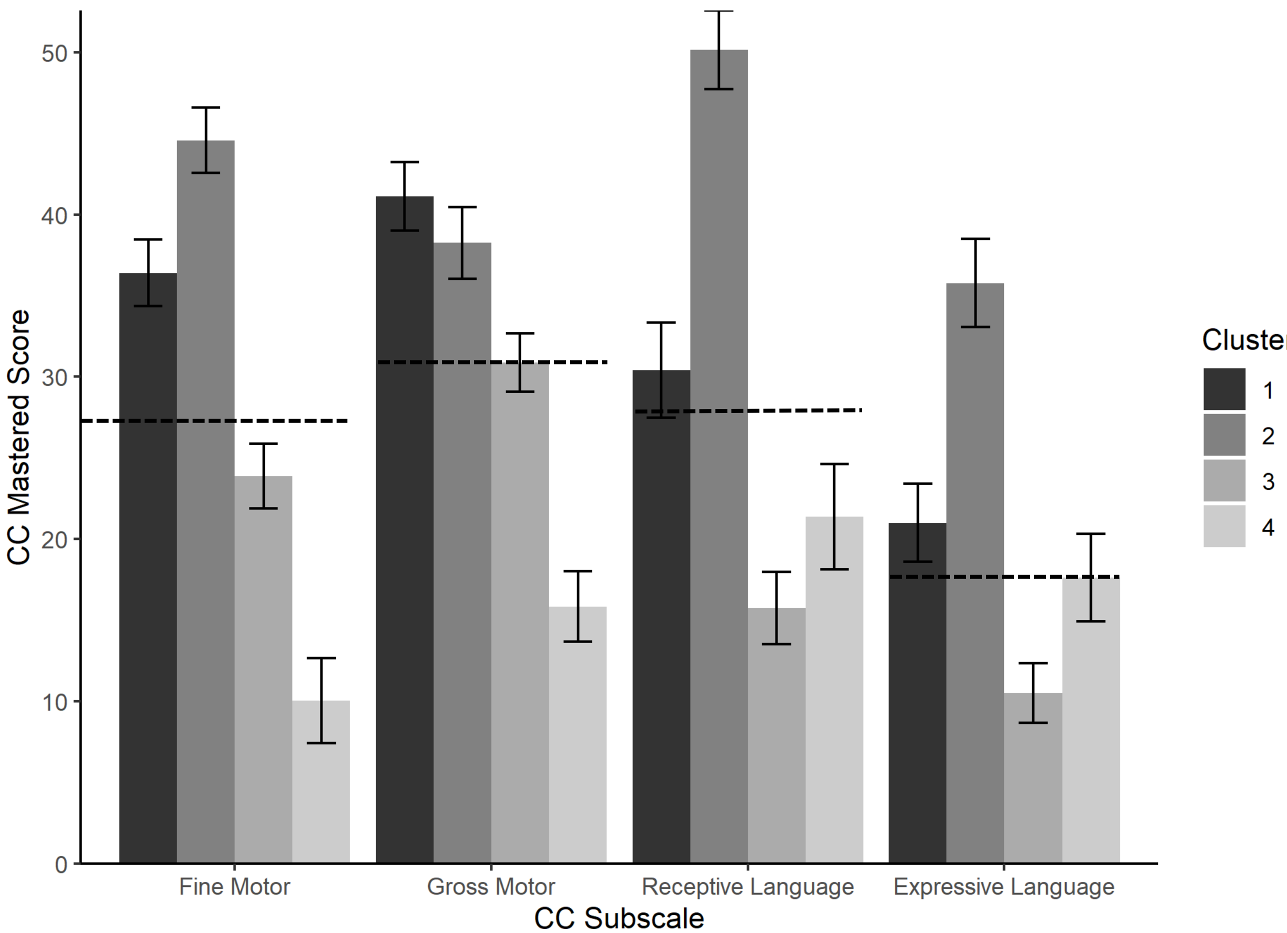
Table 5

Cluster Z-Scores of the CC Subscales

	Cluster 1 N = 11	Cluster 2 N = 7	Cluster 3 N = 12	Cluster 4 N = 8
Fine motor	.63051	1.19549	-.23707	-1.19530
Gross motor	.88127	.64642	.04161	-1.19109
Receptive language	.15061	1.42747	-.79789	-.43393
Expressive language	.26624	1.52012	-.62419	-.01997

Figure 5

CC Subscale Scores According to Cluster Membership

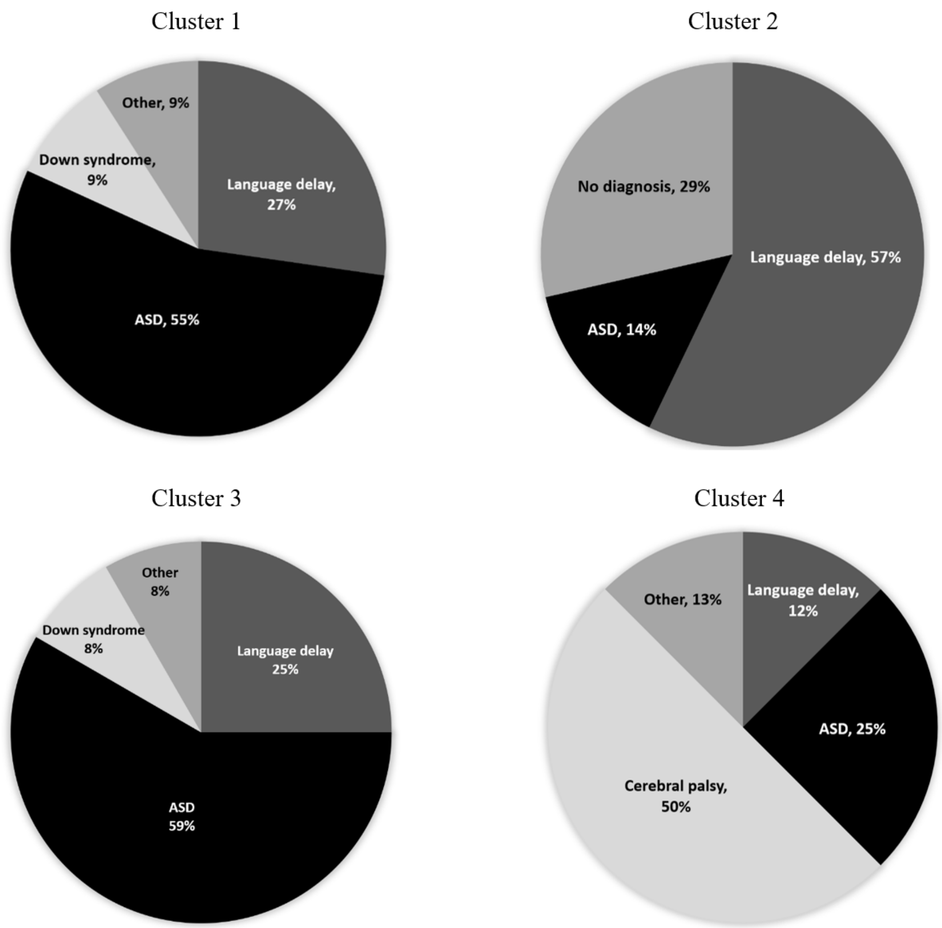


Note. Dashed lines represent sample means per subscale. Error bars represent +/- *SE*. Cluster 1: high fine motor, high gross motor, average receptive language, average expressive language; Cluster 2: high fine motor, high gross motor, high receptive language, high expressive language;

Cluster 3: average fine motor, average gross motor, low receptive language, low expressive language; Cluster 4: low fine motor, low gross motor, average receptive language, average expressive language.

Figure 6

Diagnostic Composition of the Different Clusters



Note. Cluster 1: high fine motor, high gross motor, average receptive language, average expressive language; Cluster 2: high fine motor, high gross motor, high receptive language, high expressive language; Cluster 3: average fine motor, average gross motor, low receptive language, low expressive language; Cluster 4: low fine motor, low gross motor, average receptive language, average expressive language.

Discussion

The present study endeavoured to explore associations between motor and language abilities in children with developmental disabilities. The aims of the study were to explore whether there are associations between overall motor and overall language abilities and between subtypes of motor and language abilities (e.g. fine motor, gross motor, receptive language, expressive language) across diagnosis, and whether there are profiles of scores related to these subtypes of motor and language abilities. Overall, in support of embodied cognition, robust associations were demonstrated between motor and language abilities even in a heterogeneous sample of children with multiple developmental disabilities. The findings highlight that cognition is dependent on other domains of development (Meteyard et al., 2012). Moreover, cognitive processes must be grounded in sensorimotor interactions with the environment (Iverson, 2010; Lakoff, 1987; Wilson, 2002). Moreover, even if children have impairments in one or more domains of development, embodied processes persist. Unembodied theories are not supported by the findings of the present study, since the presence of associations between motor and language abilities demonstrates that cognition is not independent or domain-specific (Fodor, 1983). Secondary embodiment, which posits that cognition is independent from sensorimotor information (Mahon & Caramazza, 2008), is also not supported by the present study’s findings. However, this perspective proposes that there are still associative connections between language and motor domains, which is supported by the results of the present study. Moreover, differential associations were demonstrated between fine versus gross motor abilities and language, which advocates for a weak rather than strong theory of embodied cognition. Strong embodiment proposes that cognition is completely dependent on sensorimotor information (Meteyard et al., 2012), and that sensorimotor information is activated in all cognitive processes (Barsalou, 1999). However, there were stronger associations between fine motor abilities and language compared to gross motor abilities and language. Therefore, the present study's findings align most closely with weak embodiment, which asserts that cognition is partially constituted by sensorimotor information, and when activated during cognition, sensorimotor information has a representational role rather than being secondary to abstract cognition (Meteyard et al., 2012).

Consistent with my hypothesis, overall motor and overall language scores were strongly correlated, and overall motor scores significantly predicted overall language scores across diagnosis. This association is supported by theoretical perspectives which advocate that motor abilities such as gesture, crawling, and walking provide increased opportunities for linguistic development (Iverson, 2010). Various studies of children with single developmental disabilities have also demonstrated associations between these domains of development (Finlay & McPhillips, 2013; Lipscombe et al., 2016; West, 2018). In studies of children with multiple developmental disabilities similar to the present study, relationships have been demonstrated between overall motor skills and spelling (Vuijk et al., 2011), fine motor abilities and overall language (Whitmore, 2015), and gross motor abilities and overall language (MacDonald et al., 2017). The present study adds to existing literature, demonstrating that robust associations persist between overall motor and overall language abilities across diagnosis in a heterogeneous sample of children with developmental disabilities.

Along with overall motor and overall language abilities, associations also emerged between subtypes of these abilities. Consistent with my hypothesis and typically developing literature (Moore et al., 2019; Salavati et al., 2017), fine motor abilities demonstrated strong correlations with receptive and expressive language across diagnosis. Moreover, fine motor abilities predicted receptive and expressive language. These findings are supported by various studies that have established relationships between fine motor abilities such as pointing, gesture, and manual dexterity and receptive and expressive language in children with a single developmental disability (Charman et al., 2003; Choi, Park, Choi, et al., 2018; Riou et al., 2009; Vukovic et al., 2010). A study of children with multiple developmental disabilities demonstrated associations between object use and receptive and expressive language (Delehanty et al., 2018). Findings from another study revealed that the imitation of simple movements predicted expressive, but not receptive language across diagnosis (Thurm et al., 2007). These studies of children with multiple developmental disabilities only assessed specific fine motor abilities. The present study was the first to demonstrate associations between overall fine motor skills including imitation, object use, and gesturing, and expressive and receptive language in a sample of children with multiple developmental disabilities.

In line with my hypothesis, gross motor abilities were moderately correlated with and predicted expressive language. Prior work has resulted in conflicting findings. Studies of typically (He et al., 2015; Muluk et al., 2014) and atypically developing children (LeBarton & Landa, 2019; Leonard et al., 2015; Müürsepp et al., 2011; Yamauchi et al., 2019) have similarly discovered that gross motor skills such as crawling and walking are associated with expressive language, while other studies of typically (Moore et al., 2019) and atypically developing children (Belmonte et al., 2013; Dadgar et al., 2017; Kim, 2008) have not. Findings from the present study also revealed that gross motor abilities were not associated with receptive language, which was not in line with my hypothesis. Similar results were demonstrated in one study of infants at risk for autism spectrum disorder (Leonard et al., 2015). Other literature has established that gross motor abilities such as sitting and walking are associated with receptive language in both typically (He et al., 2015; Libertus & Violi, 2016; Walle, 2016) and atypically developing children (Bedford et al., 2016; Leonard, 1998; Yamauchi et al., 2019). In studies of children with multiple developmental disabilities, one found moderate correlations between ball play and reading across diagnosis (Vuijk et al., 2011). Another study of preschoolers with developmental delay, speech/language delay and ASD found that gross motor abilities mediated the effect of age on receptive, expressive, and written language (MacDonald et al., 2017). The present study revealed different findings, demonstrating direct relationships between gross motor abilities and expressive language, but not gross motor abilities and receptive language in a sample of children with additional diagnoses such as cerebral palsy and Down syndrome.

Similar to the present study, stronger associations were demonstrated between fine motor abilities and language compared to gross motor abilities and language in a review examining these abilities in typically developing children (Gonzalez et al., 2019). This review found that in studies that measured both fine and gross motor abilities in relation to language, fine motor abilities demonstrated a higher frequency of significant relationships to language than gross motor abilities (e.g. Wolff & Wolff, 1972; Houwen et al., 2016; Lyytinen et al., 2001). These patterns in the present study may have emerged due to the fine and gross motor items on the CC. The gross motor subscale was derived from the Upright: Posture & Locomotion and Upright: Outdoor Play scales. These scales include items such as sitting, jumping, running, walking, exploring play equipment, riding bicycles, and playing games. On the other hand, the fine motor subscale was derived from the Imitation: Motor and Bilateral Skills scales, which include items such as imitating movements of caregivers, gesturing, object manipulation, and playing with caregivers. It is evident that the gross motor items on the CC involve less social interaction with caregivers compared to the fine motor items. In children with developmental disabilities such as ASD who have co-occurring impairments in social skills (American Psychiatric Association, 2013), the gross motor abilities may have developed with minimal social interaction. Social skills demonstrate strong associations with language (Brinton & Fujiki, 1993; Carvalho et al., 2016; McCabe & Meller, 2004; Pakarinen et al., 2018; Vuksanovic, 2015). Therefore, it is understandable that there were stronger associations between fine motor abilities and language compared to gross motor abilities and language in the present study. Additionally, the Outdoor Play scale on the CC was not significantly correlated to any of the language scales, whereas other motor scales on the CC were correlated. This scale contained items such as climbing ladders, using slides and walking on moving surfaces. Although gross motor skills demonstrate associations with language, these items did not involve as much social interaction as other gross motor scales on the CC (e.g. Bilateral Skills). Moreover, this scale contained fewer items than the Upright: Posture & Locomotion, Imitation: Motor, and Bilateral Skills scales, so it may not have been able to capture as much variability in motor functioning.

Results from the k-means cluster analysis revealed four distinct clusters of scores related to the subtypes of motor and language abilities: 1) high fine motor, high gross motor, average receptive language, average expressive language; 2) high fine motor, high gross motor, high receptive language, high expressive language; 3) average fine motor, average gross motor, low receptive language, low expressive language; and 4) low fine motor, low gross motor, average receptive language, average expressive language. Overall, children demonstrated either a positive (Cluster 2) or negative (Clusters 1, 3 and 4) association between motor and language abilities. Similar to the present study, other studies have also clustered children with developmental disabilities based on their performance across several domains of development (Stone et al., 1999; Wiggins et al., 2017; Yang et al., 2016). One study discovered clusters of autistic children with either positive or negative relationships between nonverbal skills (e.g. fine motor skills) and verbal skills (e.g. receptive and expressive language) (Kim et al., 2016).

However, this study only assessed fine motor, receptive language, and expressive language abilities in children with ASD. The present study was the first to form clusters of children with multiple developmental disabilities based on their fine motor, gross motor, receptive language, and expressive language scores.

Children with ASD were present in all four clusters, with the most in Clusters 1 and 3, and the least in Cluster 2. Patterns revealed in Cluster 2 of a positive association between motor and language abilities are supported by various studies investigating motor and language abilities in children with ASD (Bedford et al., 2016; Choi, Leech, Tager-Flusberg, et al., 2018; Hellendoorn et al., 2015; LeBarton & Landa, 2019; Leonard et al., 2015; Luyster et al., 2008; McDuffie et al., 2005; Sparaci et al., 2018; Toth et al., 2006). One study demonstrated findings consistent with the negative associations seen between motor and language abilities in Clusters 1, 3, and 4, in that gesture items on the Autism Diagnostic Observation Schedule were negatively correlated with expressive and receptive language ratio scores (Manwaring et al., 2017; Mody et al., 2017).

Children with language delay were also present in all four clusters, with the most participants in Cluster 2 and the least in Cluster 4. Studies have shown that in children with specific language impairment (SLI) who have lower expressive and receptive language abilities, there are co-occurring deficits in fine and gross motor abilities (Hill, 2001; Müürsepp et al., 2011; Sanjeevan et al., 2015), which refutes the negative associations demonstrated in Clusters 1, 3, and 4. Another study found that the imitation of fine motor movements positively predicted expressive vocabulary in children with SLI, consistent with the patterns seen in Cluster 2 (Vukovic et al., 2010). Other studies have demonstrated findings consistent with the patterns seen in Clusters 1 and 3 of higher motor abilities compared to language abilities (Blake et al., 2008; Evans et al., 2001; Iverson & Braddock, 2011; Mainela-Arnold et al., 2006). These researchers hypothesized that advanced motor abilities such as gesturing may serve compensatory roles in children with SLI who have impaired expressive and receptive language abilities.

Children with Down syndrome were distributed evenly between Clusters 1 and 3. Children in these clusters demonstrated negative associations between motor and language abilities, in that they had higher motor abilities than language abilities. This finding has been demonstrated in one study, which found that gestural abilities in children with Down syndrome were more advanced compared to their vocal production abilities (Caselli et al., 1998). Other studies demonstrated positive associations between gross motor abilities and language (Yamauchi et al., 2019) and fine motor abilities and language (Mundy et al., 1995), which was not demonstrated in the present study.

All children with cerebral palsy were in Cluster 4. Children in this cluster demonstrated a negative association between motor and language abilities, in that they had lower motor abilities compared to language abilities. Contrary to the patterns seen in this cluster, other studies have demonstrated positive associations between motor abilities and language (Choi, Park, Choi, et al., 2018; Geytenbeek et al., 2015; Hidecker et al., 2012; Parkes et al., 2010). No current literature investigating the associations between motor and language abilities in children with cerebral palsy demonstrated the patterns seen in Cluster 4 of a negative association between motor and language abilities.

Investigating clusters of motor and language scores enables researchers to capture the heterogeneity of the abilities of children with developmental disabilities in a more meaningful way. Only examining associations between motor and language abilities elicits a limited view of the abilities of these children as it does not account for the variability within this population. For instance, children in Cluster 2 had high motor and language abilities, whereas children in Clusters 1, 3, and 4 demonstrated compensatory effects, in that motor abilities were high and language abilities were low or vice versa. Strengths or weaknesses in one developmental domain can have flow-on effects, resulting in co-occurring impairments or proficiencies in other domains of development, which corresponds with the pattern seen in Cluster 2. On the other hand, stronger abilities facilitate performance on tasks that depend on impaired abilities (Dyck et al., 2006), which is similar to the patterns seen in Clusters 1, 3, and 4. Therefore, along with exploring associations between motor and language abilities, it is important to understand whether these associations demonstrate compensatory effects, or result in co-occurring strengths or weaknesses in abilities. Ultimately, understanding the variability of abilities when investigating motor and language development aids in providing a more individualized approach to intervention for children with developmental disabilities. Moreover, understanding the developmental profile of an individual child provides more streamlined intervention strategies.

Limitations

A key limitation of the present study was that there was no control group assessed on motor and language abilities. Due to this, it was difficult to compare the performance of children with developmental disabilities to a typically developing population. The inclusion of a control group aids in exploring how the relationship between motor and language development differs in typically developing versus atypically developing children, and whether this hinders or fosters overall development. Moreover, it was difficult to ascertain whether scores on motor and language abilities were high or low compared to typically developing children. For instance, results indicated that individuals in Cluster 1 had average receptive and expressive language scores. However, these scores were on the lower end of the range of possible scores for receptive and expressive language assessed on the CC. Therefore, having a control group would be beneficial to create a benchmark of average performance on motor and language abilities.

Another limitation was that although the sample consisted of children with multiple developmental disabilities, majority of the participants were individuals with ASD and language delay. Only a few participants had diagnoses of cerebral palsy, Down syndrome, and global developmental delay. Therefore, the sample was not an accurate reflection of a truly heterogeneous population. Relatedly, although the current study was able to detect associations between motor and language abilities across diagnosis, diagnosis-specific patterns may have been masked by combining multiple diagnostic groups. However, there were not enough participants in each diagnostic group to enable the exploration of associations between motor and language abilities within diagnosis.

Another limitation of my study was that there was no measure of the severity of the diagnoses of the children with ASD, language delay, cerebral palsy, Down syndrome, and global developmental delay. Having an indication of diagnosis severity for these children would provide more information on the overall functioning of these children. Relatedly, having a measure of cognitive functioning such as IQ would be beneficial since cognitive abilities demonstrate relationships with language and motor functioning (Cleland et al., 2009; Higashionna et al., 2017). Similarly, measuring adaptive skills and collecting demographic information is important as these abilities demonstrate relationships with motor and language development (Pungello et al., 2009; Liss et al., 2001; Ferreira et al., 2018).

Lastly, the CC is not a standardized assessment, which limits the generalizability and replicability of the findings. The CC has a multitude of benefits since it is observational, transdisciplinary, and facilitates a direct link between assessment and intervention. However, it has not been standardized or normed, so results from the present study cannot be extended to explore whether associations between motor and language abilities persist in different samples (e.g. other developmental disabilities) and study designs (e.g. longitudinal studies).

Implications and Future Directions

The robust associations that were demonstrated between motor and language abilities across diagnosis advocates for a transdiagnostic approach to assessment and intervention. This approach, which originated from cognitive behavioural theories, cuts across categorical diagnoses to inform therapy (Fusar-Poli et al., 2019). In the present study, children with different diagnoses were distributed across the four clusters and several children had multiple diagnoses, suggesting that children should be understood based on their abilities rather than their diagnostic classification. A traditional approach, which focuses on diagnostic categories rather than abilities, fails to acknowledge high rates of comorbidity across developmental disorders and heterogeneity within disorders (Msall et al., 1998; Munson et al., 2008; Tek et al., 2014). The *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, 2013) details that many disorders co-occur with ASD, such as language disorder (Boucher, 2012; Conti-Ramsden et al., 2006; Ozonoff et al., 2014), global developmental delay (Christensen et al., 2018; Flanagan et al., 2015; Shevell et al., 2005), intellectual disability (Srivastava & Schwartz, 2014), attention-deficit hyperactivity disorder (Leitner, 2014), and Down syndrome (Kent et al., 1999). In addition to the high co-occurrence rate between developmental disabilities, there is significant overlap among the core symptoms of these conditions, so it is more realistic to identify symptom-specific deficits rather than diagnosis-specific deficits (Craig et al., 2016; Cuthbert & Insel, 2013; Owen et al., 2014). Symptoms traditionally linked with one developmental disorder might trigger co-occurring symptoms commonly associated with a different disorder. Moreover, even if the symptoms are different, there may be a common etiology for certain developmental disabilities (Gilger & Kaplan, 2001). Therefore, rather than identifying diagnostically distinct subtypes, it is more beneficial and realistic to describe multidimensional symptoms of behaviour and abilities across diagnosis. Adopting this transdiagnostic approach to investigate the associations between developmental domains aids in identifying patterns that may be shared by numerous disabilities. Overall, the co-occurrence of delays in multiple areas, comorbidities between diagnoses, and shared symptoms between different diagnoses should be considered in designing transdiagnostic intervention strategies for children with developmental disabilities (Stich et al., 2014).

Ascertaining the nature of the relationship between motor and language abilities in children with developmental disabilities is pertinent to comprehensively understanding child development. Examining development from this holistic perspective is crucial because children naturally engage with their environment using interacting abilities (Bell et al., 2010). Exploring associations between motor and language development can help researchers and clinicians understand whether strengths in certain areas of development can bolster other areas. This will allow researchers to examine if interventions to support development in one domain will facilitate development in another. Since robust associations and profiles are seen in such a heterogenous sample of children with varying abilities and diagnoses, intervention efforts encompassing both motor and language development can be universally applied across diagnosis. Taking this all-encompassing approach will ensure children's full range of needs can be targeted appropriately. The present study underscores the importance of assessing each child's capacities across a broad range of abilities, so it is important to assess how strengths or weaknesses in one domain may be affecting performance in other domains (Dyck et al., 2006). Detailed information regarding children's strengths and weaknesses across dimensions of functioning will aid in designing more differentiated intervention programs. Overall, examining and nurturing children's cognitive, social, and motor development together will aid in optimally improving outcomes for children with developmental disabilities.

Future directions include recruiting a control group to evaluate whether associations between motor and language abilities are revealed in a sample of typically developing children. Moreover, recruiting additional participants within each of the diagnostic groups will allow researchers to investigate patterns of motor and language abilities both within and across diagnosis. Additionally, comparing the CC to standardized assessment measures such as the Adaptive Behaviour Assessment System, Third Edition (ABAS-3; Harrison & Oakland, 2015) will be beneficial to determine whether findings from the CC are generalizable and replicable. Moreover, the present study only investigated mastered skills on the CC, so future studies should investigate associations between emerging motor and language abilities in children with developmental disabilities. Lastly, in order to understand both typical and atypical developmental trajectories, it is important to assess how strengths or weaknesses in one domain may affect performance in other domains, which requires longitudinal research. Future research should aim to investigate longitudinal changes in these associations between motor and language abilities in children with multiple developmental disabilities. Longitudinal designs will allow researchers to determine whether earlier milestones can predict later abilities and thus whether intervention can bolster earlier abilities to prevent detrimental effects later in life.

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Appendix

The Carolina Curriculum for Infants, Toddlers, and Preschoolers with Special Needs, Second & Third Edition

The Carolina Curriculum for Infants, Toddlers, and Preschoolers with Special Needs

SECOND & THIRD EDITION

Assessment Log and Developmental Progress Chart

Child's name:

Child's date of birth:

Family's name:

Name of person(s) completing form:

Directions:

Assessment Log: Insert the date of your assessment at the top of the column and insert a + in the box for each mastered item, a +/- for an inconsistent or emerging skill, and a – for a skill the child is unable to do. When working with a child with severe motor impairments, it is useful to add an **A** alongside the + or +/- to indicate that the child accomplished the task with physical assistance.

Developmental Progress Chart: Each item on the Assessment Log is represented by a square on the Developmental Progress Chart. Using a highlighter or other colored writing instrument, fill in the squares associated with items marked with a +. Make a diagonal line through squares associated with items marked with a +/- and color them in halfway. Those marked with a – should be left blank. Complete the chart by filling in the squares preceding the age span in which all items were passed. When working with a child with sever motor impairments, it is useful to add an **A** to the box to indicate that the child accomplished the task with physical assistance.

ASSESSMENT LOG

**** Consult with team members if you feel you are unable to administer items as described.**

Form	Age	Curriculum Sequences	Mastery (-/+)	Notes
Personal-Social				
1. Self-Regulation and Responsibility				
Infants and Toddlers	0-3	a) Stops crying when sees or touches bottle or breast		
		b) Can be comforted by being spoken to, held, or rocked		
		c) Calms when swaddled		
	3-6	d) Comforts self		
	6-9	e) Entertains self with toys for short periods of time		
	9-12	f) Moves away from the primary caregiver who is in the same room		
	12-15	g) Moves partially out of the primary caregiver's sight for short periods of play		
		h) Gets toys to play with from a box or shelf of toys		
	15-18	i) Plays alone with toys for 15 minutes		
	18-21	j) Puts away toys in correct places		
		k) Explores		
	21-24	l) Tolerates being taken into a variety of environments		
Overlap	24-30	m) Avoids common dangers		
		n) Plays comfortably in a small group of children		
	30-36	o) Knows what toys can and cannot do and uses them appropriately		
Preschoolers	36-42	p) Puts away toys neatly when asked (may have to be reminded)		
		q) Follows rules given by adults for new activities or simple games		
		r) Adapts readily to changes in routine		
	42-48	s) Answers questions related to safety		
		t) Shows care in handling small animals or potentially breakable objects		
	48-54	u) Performs simple chores (may have to be reminded or supervised)		
		v) Responds appropriately to instructions given in a small group		
	54-60	w) Buys simple objects in store without help (i.e., gets object or has clerk get object, gives money, and waits for change)		

		x) Answers telephone appropriately and calls person to telephone		
2. Interpersonal Skills				
Infants and Toddlers	0-3	a) Smiles to auditory and tactile stimulation		
		b) Smiles reciprocally		
		c) Smiles at family		
	3-6	d) Laughs		
		e) Tries to attract attention by making sounds, smiling, making eye contact, or using body language		
	6-9	f) Responds differently to family members and strangers		
		g) Participates in simple games		
		h) Repeats activity that elicits laughter from observer(s)		
	9-12	i) Shows an interest in other children – tries to attract their attention through eye gaze, smiles, and vocalizations		
		j) Initiates playing games		
		k) Laughs or smiles at adults who are engaging in unexpected behaviors		
	12-15	l) Spontaneously shares with adults		
		m) Shows affection		
	15-18	n) Tries to please others		
		o) Plays alongside other children (some exchange of toys)		
		p) Plays simple interactive games with other children		
	18-21	q) Helps with simple household tasks		
		r) Approaches peer or adult to initiate play		
	21-24	s) Responds appropriately to social contact made by familiar adults		
		t) Tries to comfort others in distress		
		u) Spontaneously shares with peers, often briefly		
		v) Tries to help by running errands on request or anticipating what is needed		
Overlap	24-30	w) Negotiates with peers about toys (may trade)		
		x) Shows awareness of social standards (e.g., wants clothes changed when dirty, brings broken toys to be fixed)		
	30-36	y) Works collaboratively toward a goal with peers		
		z) Expresses affection and/or preference for some peers		
		aa) Expresses regret when another child is hurt or experiences unpleasantness		

		bb) Requests permission		
Preschoolers	36-42	cc) Converses with peers		
		dd) Takes turns most of the time if reminded		
		ee) Responds appropriately to social contact made by familiar adults		
		ff) Separates easily from parents or caregiver in familiar surroundings		
		gg) Prefers interacting with peers to being with adults		
		hh) Cooperates with peers to develop a theme for imaginative play		
	42-48	ii) Labels feelings or peers and responds to them		
		jj) Plays group games with other children without constant adult supervision		
		kk) Plays simple board or card games with other children with adult supervision		
		ll) Negotiates conflicts verbally		
		mm) Listens to peers and discusses ideas or observations		
		nn) Demonstrates understanding that different people have different feelings, attitudes, or beliefs through role playing in pretend play		
	48-54	oo) Asks permission to use other people's belongings		
		pp) Shows awareness of other people's feelings		
		qq) Uses terms such as "thank you," "please," and "you're welcome" appropriately		
		rr) Recognizes another's need for help and gives assistance		
		ss) Plays cooperatively with peers for extended periods without requiring adult intervention		
		tt) Plays familiar games with peers and follows the rules without adult intervention		
	54-60	uu) Identifies special friends		
		vv) Spontaneously takes turns and shares		
		ww) Asserts self in socially acceptable ways		
		xx) Plans/creates games that have rules with peers		
		yy) Demonstrates an interest in people outside of the family and immediate circle of friends		
Cognition				
7. Functional Use of Objects & Symbolic Play				
	0-3	a) Moves hand to mouth		
		b) Explores objects with mouth		

	3-6	c) Plays with (e.g., shakes, bangs) toys placed in hand		
		d) Commonly performs four or more activities with objects		
		e) Responds differently to a different toy in a group of similar toys		
	6-9	f) Demonstrates appropriate activities with toys that have obviously different properties		
		g) combines two objects in a functional manner		
	9-12	h) Orients materials appropriately (e.g., turns cup right side up, places cars on wheels)		
		i) Manipulates books by looking, patting, pointing, or turning pages (may use as a hinge)		
	12-15	j) Plays spontaneously with a variety of objects, demonstrating their functions		
	15-18	k) Experiments with unfamiliar objects to determine their functions		
	18-21	l) Spontaneously engages in adult activities with props		
	21-24	m) Engages in adult role (e.g., cooks, hammers, talks on play telephone)		
		n) Pretends that objects are something other than what they are (e.g., blocks are food)		
Overlap	24-30	o) Talks to dolls or animals and/or makes them interact with one another		
	30-36	p) Assumes different roles in fantasy play		
		q) Represents more complex events in play		
		r) Uses different voices for different people in play		
Preschoolers	36-42	s) Pretend play includes a logical sequence (with three to four parts) that evolves as play proceeds		
		t) Uses materials to construct other objects		
	42-48	u) Uses dolls, stuffed animals, or puppets as participants in play (gives dialogue to them)		
		v) Describes own activities during play		
	48-54	w) Builds large structures from blocks or chairs and centers play around them		
		x) Cooperates with others in pretend play (discusses roles)		
	54-60	y) Uses toy animals or dolls to act out "What would happen if…?"		
		z) Engages in complex adult role playing		
8. Problem Solving/Reasoning				
	0-3	a) Shifts attention (i.e., visual fixation, body orientation) from one object to another		

		b) Looks for or reaches toward objects within sight that touch the body		
		c) Repeats activities that produce interesting results		
	3-6	d) Plays with toys placed in hands		
		e) Persists in efforts to obtain an object or create an effect		
		f) Repeats activities that elicit interesting reactions from others		
	6-9	g) Looks for or reaches towards objects that make noise while falling from view		
		h) Looks for or reaches toward objects that fall quietly from view		
		i) Looks or moves in correct direction for objects that fall and roll or bounce to a new location		
		j) Overcomes obstacles to get toys		
		k) Plays with a variety of toys to produce effects		
	9-12	l) Increases rate of usual activity with toy when it stops working or tries another activity to make toy work		
		m) Retrieves toys from container when they have been dropped through a hole in the top of container		
	12-15	n) Reaches object from behind a barrier		
		o) Pulls string to get object from behind a barrier		
		p) Moves self around a barrier to get object		
	15-18	q) Uses adults to solve problems		
		r) Solves simple problems without adult assistance		
	18-21	s) Retrieves familiar objects from usual locations in another room on request		
		t) Pus away objects in correct places		
	21-24	u) Uses tools to solve problems		
		v) Independently plays with toys that require pushing buttons, pulling strings, and/or operating switches to get effects		
Overlap	24-30	w) Experiments with cause and effect when playing		
		x) Independently nests four containers, stack rings, or blocks of graduated sizes		
		y) Comments that something is not working when expected effects are not produced		
	30-36	z) Independently explores objects to determine their function and/or shows other people how they work		
		aa) Answers at least one “why do” question correctly		

Preschoolers	36-42	bb) Identifies silly or wrong pictures or events		
		cc) Finds items that go together when asked, “Which one goes with this?”		
		dd) Completes sequences of colors or shapes		
		ee) Tells how an object is used when asked, “What do you do with this?”		
		ff) Answers two or more “what do you do when” questions		
	42-48	gg) Answers question (or points to pictures) to indicate where things come from or what they are made of		
		hh) Describes simple absurdities seen in pictures or real life		
		ii) Responds appropriately to “tell me how” or “how do you” questions		
		jj) Completes two analogies (i.e., sentences involving comparisons, such as “Brother is a boy, sister is a girl”)		
	48-54	kk) Identifies missing parts in pictures		
		ll) Imagines and describes what will happen next in unfamiliar story or pictures		
		mm) Reasons about experiences and asks and answers questions		
		nn) Describes new uses for familiar objects		
	54-60	oo) Describes similarities between two different objects		
		pp) Reasons about future events		
Communication				
9. Verbal Comprehension				
Infants and Toddlers	0-3	a) Appropriately reacts to tone of voice and/or some facial expressions		
	3-6	b) Turns to the direction from which name is being called		
		c) Stops activity when name is called		
	6-9	d) Does previously learned task on verbal or gestural cue		
		e) Responds with correct gestures to “up” and “bye-bye”		
		f) Responds to “no” (briefly stops activity)		
	9-12	g) Responds to “give me” (spoken or signed)		
	12-15	h) Follows two or more simple commands (one object, one action), spoken or signed		
		i) Appropriately indicates “yes” or “no” in response to questions		

	15-18	j) Retrieves objects within view on verbal or signed request		
	18-21	k) Understands "look"		
	21-24	l) Understands words used to inhibit actions (e.g., "wait," "stop," "get down," "my turn")		
		m) Follows commands in familiar contexts		
Overlap	24-30	n) Follows 2-part related commands in novel contexts		
	30-36	o) Follows 3-part commands (three objects and one action, three actions and one object, or three objects related by activity)		
Preschoolers	36-42	p) Responds to yes/no questions with appropriate words or gestures		
		q) Understands negatives		
		r) Sorts by color on verbal discretion (no sample)		
	42-48	s) Follows 2-step commands involving sequence		
		t) Sorts by named categories		
	48-54	u) Follows 3-step instructions in sequence involving two to three different objects		
		v) Responds appropriately to statements or questions involving regular plurals		
		w) Points to pictures or selects objects from a group based on object class and 2 characteristics		
	54-60	x) On verbal direction (no sample), sorts objects on the basis of 2 characteristics		
		y) Follows directions including "before" and "after"		
		z) Follows instructions that include 4 elements		
10. Conversation Skills				
	0-3	a) Smiles to person who is talking and/or gesturing		
		b) Provides consistent signals for states of hunger, distress, and pleasure		
		c) Protests by vocalizing disapproval of actions and/or events		
		d) Vocalizes five or more consonant and vowel sounds		
		e) Laughs		
	3-6	f) Repeats vocalizations and/or gestures that elicit reactions		
		g) Indicates interest in toy or object through eye gaze, reaching, or vocalization		
		h) Requests continued action of familiar toy, song, or activity by body movements, eye contact, and/or vocalizations		
		i) Waits fort adult to take a turn		

		j) Begins to coordinate looking with listening		
		k) Makes requests by directing caregiver's attention		
	6-9	l) Indicates "no more" and "I don't like this" by vocalization, turning, or pushing away		
		m) Notices and vocalizes when primary caregiver prepares to leave		
		n) Uses eye gaze to select another person as partner for a communication exchange		
		o) Changes pitch/volume to signify intensity of desires		
	9-12	p) Raises arms to be picked up		
		q) Indicates desire to "get down" or "get out" in some consistent fashion other than fussing or crying		
		r) Plays reciprocal games (e.g., Peek-a-boo, clapping, taking turns making sounds)		
	12-15	s) Uses words or signs to express wants		
		t) Seeks adult's assistance in exploring the environment by vocalizing, pointing, or using other communicative signals		
	15-18	u) Uses inflection patterns when vocalizing (or uses gestures as if signing)		
		v) Greets familiar people with an appropriate vocalization or sign		
		w) Direct caregiver to provide information through pointing, a questioning look, vocal inflection, and/or words		
	18-21	x) Says (or signs) "no" to protest when something is taken away		
		y) Experiments with two-word utterances or two-sign gestures to achieve specific goals		
	21-24	z) Spontaneously says (or signs) familiar greetings and farewells at appropriate times		
		aa) Says (or signs) "yes" and "no" to indicate desires or preferences		
		bb) Spontaneously uses words (or signs) in pretend play		
		cc) Uses words or signs to request actions		
		dd) Answers simple questions with a verbal response, gesture, or sign		
	24-30	ee) Asks simple questions with vocalization or gesture		
		ff) Asks yes/no questions with appropriate inflection		
		gg) Requests assistance		

		hh) Uses words or sign combinations to describe remote events		
	30-36	ii) Comments on appearance or disappearance of objects or people		
		jj) Sustains conversations for several turns		
		kk) Reads books to others by making multiple-word utterances		
		ll) Responds appropriately to "where" and "why" questions		
Preschoolers	36-42	mm) Changes speech depending on listener		
		nn) Talks on telephone and waits for turn to respond		
		oo) Uses words to describe attributes of toys, foods, or other objects		
		pp) Describes events occurring in the environment		
		qq) Answers "what is," "whose," "who," "and how many" questions appropriately (if not correctly)		
	42-48	rr) Names three or more elements or describes what is happening when asked to tell all about a picture or storybook		
		ss) Responds appropriately to "what do you do" and "why do we" questions		
		tt) Reads a story aloud to self or another person while looking at pictures in a book		
		uu) Describes functions or objects		
	48-54	vv) Communicates cause and effect relationships		
		ww) Asks questions related to another person's statement in order to maintain a conversation		
		xx) Creates interest in a listener by indirect references		
		yy) Communicates knowledge about the world to peers and adults		
	54-60	zz) Explains social conventions or rules to peers		
		aaa) Asks and responds appropriately to "how far" questions		
Fine Motor				
11. Imitation: Motor				
	0-3	a) Looks at caregiver and makes facial movements when caregiver is talking or making noises		
	3-6	b) Continues movement imitated by caregiver		
		c) Imitates an activity in repertoire after observing caregiver doing that activity		
	6-9	d) Imitates unfamiliar movements		

	9-12	e) Imitates simple gestures, such as signaling "bye-bye" or "no"		
		f) Imitates frequently observed actions with objects (e.g., stirs with spoon)		
	12-15	g) Imitates actions related to the function of the object		
		h) Imitates gestures or signs caregiver commonly uses		
	15-18	i) Imitates activities involving a combination of objects or two actions with one object		
		j) Imitates activities involving a combination of objects several hours after observing actions		
	18-21	k) Incorporates sequence of imitated adult activities into solitary play		
	21-24	l) Attempts to solve problems (including activating toys) by imitating adult actions		
Overlap	24-30	m) Imitates postures or actions that do not involve props		
	30-36	n) Imitates sequence of 2 unrelated motor acts		
Preschoolers	36-42	o) Repeats sequence of three unrelated motor activities after being led through these activities, one by one		
	42-48	p) Imitates simple finger plays (both hands doing similar actions)		
	48-54	q) Imitates finger plays (each hand doing different actions)		
	54-60	r) Imitates complex motor activities in songs and games		
12. Bilateral Skills				
Infants and Toddlers	0-3	a) Raises both hands when object is presented (hands partially opened)		
		b) Looks at or manipulates toy placed in hands at midline		
	3-6	c) Brings hands together at midline		
		d) Places both hands on toy at midline		
		e) Transfers objects from hand to hand		
		f) Glances from one toy to another when a toy is placed in each hand, or alternatively plays with the toys		
		g) Plays with own feet or toes		
	6-9	h) Claps hands		
	9-12	i) Uses both hands to perform the same action		
		j) Plays with toys at midline (one hand holds the toy and the other manipulates it)		

	12-15	k) Pulls apart pop beads		
		l) Holds dowel in one hand and places ring over it.		
	15-18	m) Puts dowel through hole in piece of cardboard		
		n) Unwraps edible item or other small object ****Wrap small preferred toy in wax paper**		
	18-21	o) Unscrews small lids		
	21-24	p) Puts loose pop beads together		
		q) Strings three large beads		
Overlap	24-30	r) Demonstrates hand preference (typically in eating)		
	30-36	s) Unbuttons large buttons		
		t) Strings small beads		
		u) Screws on lids		
Preschoolers	36-42	v) Laces cards with large holes		
		w) Demonstrates hand preference by picking up most materials with one hand (will cross midline of body)		
	42-48	x) Ties single knot		
		y) Laces two holes in shoes		
	48-54	z) Does simple sewing		
		aa) Holds deck of cards and sorts		
		bb) Buttons ½ inch buttons		
	54-60	cc) Folds paper in half (no demonstrations)		
		dd) Consistently uses same hand for skilled activities		
Gross Motor				
22-1. Upright: Posture & Locomotion				
Infants and Toddlers	0-3	a) Holds head steady when held		
	3-6	b) Holds trunk steady when held at hips		
	6-9	c) Moves to sitting position from stomach or all-fours position		
		d) Sits alone		
	9-12	e) Pulls self to standing position		
		f) Steps sideways holding a support		
		g) Stoops to pick up toys while holding a support		
		h) Removes hands from support and stands independently		
		i) Takes independent steps		
	12-15	j) Moves from hands and knees to hands and feet to standing		
		k) Squats down to retrieve object		

	15-18	l) Walks sideways		
		m) Walks backwards at least 5 feet		
		n) Walks up three stairs, same-step foot placement, with rail		
		o) Walk down three stairs, same-step foot placement, with rail		
	18-21	p) Maintains a squatting position in play		
		q) Runs stiffly		
		r) Jumps on floor		
		s) Walks up three stairs, same-step foot placement, without rail		
	21-24	t) Jumps off stairs		
Overlap	24-30	u) Walks backward 10 feet		
		v) Walks on all types of surfaces without falling		
		x) Uses heel-toe pattern (arms free to carry objects)		
		y) Runs at least 10 feet without falling		
		z) Jumps down from 8 inch height (one foot leading)		
		aa) Walks up three stairs, alternate pattern, with rail		
	30-36	bb) Walks at least 20 feet on tiptoes		
		cc) Avoids obstacles when running		
		dd) Walks up three stairs, alternate pattern, without rail		
		ee) Walks down three stairs, same-step foot		
		placement, without rail		
		ff) Jumps over 2 inch hurdle		
		gg) Jumps down from 16 inch to 18 inch height (one foot leading)		
		hh) Broad jumps 4 inches to 14 inches		
	36-42	ii) Walks 10 feet on tiptoes on 1 inch line		
		jj) Gallops five cycles		
		kk) Runs with some periods of flight (both feet off of the ground)		
		ll) Hops in one place		
		mm) Walks up 10 stairs, same-step pattern, without rail		
		nn) Walks down 10 stairs, same-step pattern, without rail		
		oo) Jumps over 8 inch hurdle		
		pp) Jumps down from 18 inch to 24 inch height (feet together on takeoff and landing)		
		qq) Broad jumps 14 inches to 24 inches		
	42-48	rr) Skips five cycles, pausing between skips		

		ss) Hops two to three times on preferred foot		
		tt) Jumps down from 24 inch to 30 inch height (feet together on takeoff and landing)		
		uu) Walks down three stairs, alternate pattern, with rail		
		vv) Jumps over several 8 inch obstacles in succession		
		ww) Broad jumps 24 inches to 36 inches		
	48-54	xx) Walks down 10 stairs, alternate pattern with rail		
		yy) Hops five times on preferred foot, three times on non-preferred foot		
		zz) Skips 5-10 cycles, coordinated step-hop		
		aaa) Runs at least 50 feet in 10 seconds		
		bbb) Jumps 3 inches beyond arms' reach		
		ccc) Jumps down from 32 inch height (may land on one foot)		
		ddd) Broad jumps at least 36 inches		
	54-60	eee) Skips at least 15 cycles with rhythmic weight transfer (landing on toes)		
		fff) Runs, changing direction 180 degrees within four to eight steps		
		ggg) Hops forward 16 inches on preferred foot, 12 inches on non-preferred foot		
		hhh) Walks down 10 stairs, alternate pattern, without rail		
		iii) Jumps on floor, completing 180 degree turn in one jump		
22-4. Upright: Outdoor Play				
Infants and Toddlers	12-15	a) Explores play area with supervision		
	15-18	b) Enjoys swinging and sliding		
	18-21	c) Climbs on low equipment		
	21-24	d) Climbs slanted ladder		
		e) Uses slide independently		
Overlap	24-30	f) Runs on playground, pausing at surface changes		
		g) Climbs on low jungle gym bars and will drop several inches to the ground		
		h) Climbs vertical ladder		
	30-36	i) Walks on movable surfaces using some hand		
		support		
	36-42	j) Pedals tricycle at least 10 feet		
		k) Moves actively in play areas		

	42-48	l) Enjoys unsteady surfaces and tries to make them move		
		m) Runs vigorously in play areas		
	48-54	n) Pumps swing		
		o) Invents cooperative games involving equipment		
	54-60	p) Rides two-wheel bicycle		