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Describing the Motor Skills of Young Children with Developmental Delays Before and After Participating in an Augmented or Non-Augmented Language Intervention

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DESCRIBING THE MOTOR SKILLS OF YOUNG CHILDREN WITH DEVELOPMENTAL DELAYS BEFORE AND AFTER PARTICIPATING IN AN AUGMENTED OR NON-AUGMENTED LANGUAGE INTERVENTION

by

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Under the Direction of Dr. Mary Ann Romski

ABSTRACT

This study described the effect of a non-augmented (Spoken Communication, SC) and two augmented language interventions (Augmented Communication-Input, AC-I or Augmented Communication-Output, AC-O) on the upper-body, gross and fine motor skills of toddlers at the onset and conclusion of the intervention. The data presented are from a longitudinal study by Romski, Sevcik, Adamson, Cheslock, Smith, Barker, & Bakeman (2010). Three standardized assessments and five observational measures examined the participants' motor skills used to activate the speech generating device (SGD), language abilities and outcomes. The AC-O intervention decreased physical prompting, increased error-free symbol activations, and increased developmentally appropriate gross and fine motor use. An augmented intervention that utilizes a SGD may facilitate both language and motor development through the combination of the communicative goals and increased motor learning opportunities when accessing the SGD device.

INDEX WORDS: Motor development, Augmented and alternative communication, Developmental delays

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Introduction

Achievements made in motor and language development by young children are integral to their overall development. The small body of literature concerning the relationship between language and action supports the theoretical perspective of embodied cognition. This concept suggests that cognition and the cognitive processes involved in language production are influenced by the body's motor abilities and interaction with the surrounding environment (Iverson & Braddock, 2011). In other words, motor movements and interaction with the surrounding environment may significantly influence spoken language production. The motor skills acquired while interacting with the environment involves the process of motor learning (Oxendine, 1968). Examples of such interactions with the environment include climbing a jungle gym on the playground and using a fork to eat. Developmental disorders often make the acquisition of basic motor and language skills more difficult for children, and may require the use of interventions to assist and support children when learning those fundamental skills. Furthermore, a delay or impairment in one domain may increase the likelihood that a delay or impairment will occur in the other domain (Hill, 1998; Iverson, 2010; Iverson & Braddock, 2011; Owen & McKinlay, 1997; Webster, Majnemer, Platt, & Shevell, 2005).

When addressing motor impairment, activities with the purpose of strengthening a child's muscular system during physical and/or occupational therapy are often employed. Similarly for significant language delays, speech and language therapy is used to improve the communicative abilities of those children with observable language deficits. One approach to provide communicative opportunities for children who are having difficulty acquiring speech is an augmented language intervention. Language interventions that use augmentative and alternative communication (AAC) provide children with a temporary or permanent mode to communicate. AAC modes range from manual gestures to speech generating devices (SGD; Romski & Sevcik, 1997). A SGD is a speech aid that provides a mode of communication for individuals with speech impairment. When a child with functional gross motor skills wants to use a SGD symbol, he or she must extend their arm to reach the symbol. Using any level of available fine motor skills, the child directly selects a symbol to activate the device. Once the symbol is activated, a computer-generated or augmented word is produced. AAC language interventions using an SGD are focused on communication. However, they may also include a motor learning component as the result of the repetitive practice of directly selecting a SGD symbol. The opportunity to practice, incentive-driven motivation, and the generalization of device use across settings may strengthen the motor skills often impaired in individuals with speech impairments (Oxendine, 1968). Furthermore, the interaction between communicative opportunities and the utilization of available motor skills may aid in the facilitation of the motor-language development relationship.

The purpose of this study was to examine the effect of a non-augmented or one of two augmented language interventions on the relationship between the language and motor learning opportunities of children with developmental delays. Motor skills are characterized as gross, fine, visual or oral motor movements (Heller, Alberto, Forney, & Schwartsman, 1996). For the purpose of this study, the focus was on the upper-body, fine motor movements pertaining to early object manipulation and pointing, and gross motor skills involving reaching, catching, and grasping. Furthermore, the discussion of typical motor development only reviewed studies using infants as participants because the motor abilities of young children with developmental delays are often observed to be equal to the motor abilities of typically developing infants. The following introduction reviews the current literature on the suggested relationship between motor and language development, some of the current standardized measures used to assess motor skills, and AAC language interventions that utilize a SGD.

Typical and Atypical Motor Development

The acquisition and mastery of voluntary motor movements is characterized as achieving a motor milestone. Motor milestones integrate the mastery of gross and fine motor skills, and includes sitting up without support, pulling oneself up to stand, and waking alone (Haywood & Getchell, 2001). Nicolosi, Harryman, and Kresheck (1996) defined gross motor skills as movements that require the larger muscles of the muscular system and fine motor skills as movements that are spatially oriented and require the use of a smaller set of muscles. As children master one motor milestone after another, they begin to combine multiple gross and fine motor skills to execute more complex movements (Haywood & Getchell, 2001). A consistent assumption throughout the motor development research is that the sequence of early motor skills is similar, but can vary, for most typically developing children. This strongly held belief is credited to the work of Arnold Gesell, who developed the first set of developmental milestones, the *Gesell Developmental Schedules* (Gesell Institute of Human Development, 1979). Gesell's *Schedules* have been the foundation for current scales of motor, adaptive behavior, language, and personal-social development. According to the *Gesell Developmental Schedules*, typically developing children between 2 and 3 years of age are expected to be able to run, stack 6-10 blocks, turn a single page of a book, jump with two feet, and ride a tricycle (Gesell Institute of Human Development, 1979). See Appendix A for an adapted version of the *Gesell Developmental Schedule*, highlighting the typical sequence of motor development.

One of the earliest behaviors observed in infants that continue through early childhood is the exploration of the surrounding environment. Infants learn more about their environment through object manipulation. Object manipulation is also believed to be influential to overall motor development through the integration of both fine motor and perceptual skills. Rochat (1989) conducted a three-part study with infants from 2-5 months of age to examine the trajectory of object manipulation and methods used to explore various objects under certain conditions. As the infants grew older, the frequency of only grasping to explore an object decreased as the use of the finger to explore an object increased. This change was also associated with less frequent mouthing and more use of visual inspection to explore an object. Knowledge of the information gained through the exploration of the surrounding environment leads to the desire to share a common interest in an object or activity with others via the finger pointing (Adamson & Bakeman, 1991). The onset of pointing has been observed in children as young as 12 months. Pointing is used as a communicative aid for exploration, language comprehension, making declarative statements to a communicative partner, and has been shown to strongly predict future vocabulary size (Butterworth & Morissette, 1996). The onset of pointing in young children is also linked to the early ability to reach for an object, which provides similar information to pointing concerning the surrounding environment.

Early experiments have focused on adult reaching and grasping to understand the developmental sequence of the preparations and adjustments that occur before and during the action. Knowledge of adult reaching is used to examine those same preparations and adjustments in young children (Lockman, Ashmead, & Bushnell, 1984; McCarty & Ashmead, 1999; Hofsten, 1980; Hofsten & Fazel-Zandy, 1984; Hofsten & Rönnqvist, 1988). Lockman, Ashmead, and Bushnell (1984) examined the point at which infants made adjustments to their hand orientation while reaching for an object. Thirty-two 5 and 9 month-old infants were placed in a highchair in front of the reaching target. The 9 month-old infants performed better and correctly adjusted their hand orientation earlier while reaching compared to 5 month-old infants. Additionally, the manner in which infants approached the target was influenced by its position; thus, showing that older infants were able to use their motor abilities to overcome difficulties accessing the target. Hofsten and Rönnqvist (1988) also investigated the preparations and adjustments infants made while reaching and grasping for various objects. Consistent with the Lockman et al. (1984) findings, infants were observed integrating hand adjustments while reaching and grasping an object.

Catching an object utilizes similar gross and fine motor skills as compared to reaching and grasping an object. Catching skills in typically developing infants have been thought to be too complex to be achieved at a young age. Hofsten (1980) found that 9-month-old infants were able to catch an object moving approximately 60 cm/sec, with five of those infants successfully catching objects moving 30 cm/sec at 4 months of age. Infants were beginning to master reaching, grasping, and catching skills at the same time. The repetitive practice of those motor skills strengthened the relationship between those movements through active motor learning; thus, fine-tuning their ability to make the appropriate hand adjustments and preparations. The refinement of those skills is not only supported through typical developmental maturation, but also the development of other motor skills, such as postural and balance control (Heller et al., 1996). The studies reviewed demonstrated that typical motor ability became more stable as age increased, with the onset of the motor skills, frequency of interruption, and timing becoming more similar to adults (Hofsten & Rönnqvist, 1988). Knowledge of typical motor development provides an overall developmental sequence for motor development within a young, growing body and sets milestones for parents to anticipate. Deviation from the typical developmental sequence may also be used as an indicator of atypical motor development and a starting point for research conducted using children with disabilities.

Problems with motor functioning are categorized as either a motor delay or motor impairment. Children with developmental delays often exhibit some level of motor impairment, which is defined as an observed problem with the acquisition of motor skills or atypical patterns that prohibit the execution of specific movements (Mahoney, Robinson, & Fewell, 2001). For example, children with Down syndrome are frequently described as having impaired postural and voluntary motor control (Mari, Castiello, Marks, Marraffa, & Prior, 2003; Mahoney, et al., 2001; Provost, Heimerl, & Lopez, 2007a; Provost, Lopez, Heimerl, 2007b; Shumway-Cook & Woollcott, 1985). Palisano et al. (2001) created a growth curve of the gross motor skills of children with Down syndrome. Seventy-eight percent of the participants sat freely by 12 months, 92% walked without support by 36 months, and approximately 67-84% were able to run, climb stairs, and jump forward by 72 months. While the majority of participants achieved many of those milestones, the acquisition of those motor skills were delayed by at least six months as the result of motor impairment (Sattler, 2002).

The motor impairment observed in children with cerebral palsy has been studied in depth because it is a developmental disorder distinguished by impaired posture and movements. Cerebral palsy is categorized using subtypes to describe the disorder by the limbs affected and the degree of movement impairment (Batshaw, 2002). Many children with cerebral palsy require assistance being mobile through the use of crutches, walkers, or wheelchairs. The fine motor skills required for everyday hand functioning are also often impaired. Many children are unable to engage in self-care tasks or manipulate objects in their hand. Rochat (1989) demonstrated that the hand is a necessary tool to complete simple and complex tasks that permits a child to interact and learn from the environment. The degree of manual impairment may have a significant impact in the level of participation in daily activities and a child’s overall quality of life (Eliassion & Burtner, 2008). Research concerning the motor capabilities and impairment of children with cerebral palsy and Down syndrome has influenced research and interventions with other groups of children, such as children with autism spectrum disorder.

Children with autism spectrum disorder have been observed with poor balance, low muscle tone, atypical gait patterns, and problematic finger-thumb opposition (Mari et al., 2003). Comparison groups in studies have been formed using children with various developmental disorders when examining the motor abilities of children with autism spectrum disorder (Provost et al., 2007b). Provost, Heimerl, & Lopez (2007a) examined the gross and fine motor development of children with autism spectrum disorder, children with developmental delays, and children without autism spectrum disorder. The comparison group without autism spectrum disorder was not overtly characterized as typically developing. Physical therapists assessed the motor abilities of each group using the *Peabody Developmental Motor Scales-2nd Edition*. The results showed that the majority of children with autism spectrum disorder or developmental delays had equal levels of gross and fine motor skill. The remaining participants with a developmental disorder were observed to have had a decreased level of either fine or gross motor skills (Provost et al., 2007a). Results of a similar study also found that children with autism spectrum disorder, developmental delays, and various developmental concerns all exhibited similar levels of motor impairment (Provost et al., 2007b). Despite the occurrence of motor impairment, the acquisition of motor skills in atypical groups is assumed to follow a pattern similar to typically developing children, but also varies with the level of individual motor impairment.

After reviewing the literature, there is a distinguishable difference in the level of detail throughout the research concerning motor development within the typical and atypical populations. Studies with typically developing children tend to focus on specific aspects of gross or fine motor abilities, such as hand adjustments, motor planning and timing (Hofsten, 1980; Hofsten & Fazel-Zandy, 1984; Hofsten & Rönnqvist, 1988; Lockman Ashmead, & Bushnell, 1984; McCarty & Ashmead, 1999). The overall motor developmental trajectory or achievement of a motor milestone is rarely the primary focus of the results. This level of detail allows for a deeper understanding of motor development in typically developing children. Conversely, atypical motor development research has consistently reported overall motor developmental trajectories and/or abilities. When a specific aspect of motor development is further examined, it is still discussed in general levels of achievement (Palisano et al., 2001; Provost et al., 2007a; Provost et al., 2007b; Shumway-Cook & Wollcott, 1985; Wuang et al., 2008); thus, leaving the atypical motor development literature in need of more detailed descriptive information concerning the motor skills of children with developmental delays.

The Motor-Language Development Relationship

Walking and talking are the two biggest achievements children make within their first two years of life, but there has been little empirical research that has focused on the suggested relationship between motor and language development (Iverson, 2010; Meister et al., 2003; Tallal, Stark, & Mellits, 1985; Webster et al., 2005). Iverson (2010) reviewed the behavioral literature that supported the relationship between motor and language development within the context of a young, growing body. She argued that early motor behaviors, specifically rhythmic arm movements, object construction, and recognitory gestures, provided young children with the skills necessary to develop early language ability. Rhythmic arm movements, such as hand banging, allow children to practice rhythmic actions similar to and during the production of reduplicated babbling. These movements provide feedback so that children can recognize the correlation between their motor movements and complementary sound patterns (Iverson, 2010). Ejiri and Masataka (2001) observed pre-vocal behavior in Japanese infants. Infants exhibiting increased rhythmic movements and babbling acquired the oral-motor movements required to produce spoken language earlier than infants who did not produce a higher frequency of the rhythmic movements and babbling.

Iverson (2010) reviewed a study by Lifter and Bloom (1989) to support the argument that object knowledge makes use of a child's continuous motor development while acting on an object. Object knowledge also provides opportunities for a child to map specific meanings onto the whole object and influences the emergence of a child's first words. Recognitory gestures are brief actions that allow children to learn that specific meanings can be applied to objects. For example, a child picks up a toy cup and acts like he or she is drinking from the cup; thereby linking the learned action meaning to the object, a cup. Capirci, Contaldo, Caselli, and Volterra (2005) found a significant overlap in word meanings between recognitory gestures and representational gestures and/or words. Participants frequently used recognitory gestures with a similar meaning compared to representational gestures to communicate, demonstrating the link between gesture production and language development. Overall, Iverson (2010) contended that the acquisition and use of early motor behaviors fine-tunes learned motor skills that aid in language development. Understanding the role of the motor-language relationship in typically developing children sets the stage for examining that relationship in children with developmental delays.

Much of the literature concerning the motor-language relationship in children with a developmental disability has used children with developmental language disorders as the referent group (Hill, 1998; Iverson & Braddock, 2011; Owen & McKinlay, 1997; Waber et al., 2000; Webster et al., 2005). Owen and McKinlay (1997) found that 9 out of 16 participants diagnosed with developmental speech and language disorder were observed to have borderline to significant motor impairment, slower task performance, and varied hand preference (Hill, 1998; Owen & McKinlay, 1997; Waber et al., 2000; Webster et al., 2005). Similarly, Iverson and Braddock (2011) found that children with specific language impairment had significantly lower gross and fine motor skills than typically developing children, with fine motor impairment significantly predicting future language difficulties.

Hill (1998) examined arm and hand movements of children with specific language impairment and developmental coordination disorder to determine whether their motor skills were delayed compared to both age-matched and younger typically developing children. Developmental coordination disorder is a developmental disorder characterized by overall motor impairments, such as clumsiness and the failure to meet motor milestones. Children with any level of motor impairment often have skills across other domains, such as language, that resemble the abilities of young children. Children with specific language impairment and developmental coordination disorder exhibited similar motor abilities and performed the worst of all the study participants when producing representational gestures. Their impaired motor and language abilities may have affected their ability to produce representational gestures, which Capirci et al. (2005) showed to be a complex task for typically developing children. Children with specific language impairment and developmental coordination disorder also performed similarly to the younger comparison group (Hill, 1998) illustrating the effect of the presence of language or motor impairment.

Researchers have examined the motor-language relationship in children at risk for language or motor impairment. Two longitudinal studies (Lyytinen, et al., 2001;Viholainen et al., 2002) examined the effect of the familial risks for dyslexia on the achievement of developmental milestones within the first few years of life. Lyytinen and colleagues (2001) observed the influence of early, pre-verbal language skills and motor development, specifically fine motor abilities, on later language abilities. The risk for impairment of language abilities and fine motor skills were both shown to significantly predict later language skills. Viholainen et al. (2002) discovered that 38% of children with a familial risk for dyslexia were reported to have delayed gross and fine motor skills as compared to controls without a risk for dyslexia or delayed motor development. Both studies highlight the co-morbidity of language and motor impairment in young children only with a risk of impairment of one of the domains.

With little empirical behavioral research available to support the motor-language relationship, studies from the neurological literature has examined this relationship with adult participants by focusing on the motor cortex within the language dominant hemisphere of the brain. Adults are often used as participants because the tasks developed and utilized involve reading. An increase in neural excitability of the hand motor cortex within the language-dominant hemisphere of the brain has been observed while reading aloud (Meister et al., 2003). Similarly, Flöel, Ellger, Breitstein, and Knecht (2003) investigated the effect of language on hand motor excitability while completing reading speech perception, and speech production tasks. Both expressive and receptive linguistic tasks increased excitability in the hand motor cortex, further demonstrating a neural connection between the two domains in adults.

The literature review of the conceptualized motor-language relationship within typical and atypical populations suggests that there may be a relationship between the two domains. However, empirical studies regarding atypical motor development consistently focus on general developmental trajectories, and not on a detailed examination of the specific motor abilities of children with developmental delays. The lack of detailed information concerning specific motor capabilities of children with developmental delays created a body of literature with little empirical support for the motor-language relationship. Early motor activities, such as symbolic play, provide opportunities for children to practice complex language skills and are believed to activate specific motor systems and facilitate motor learning opportunities that complement such language abilities (Iverson, 2010; Miester et al., 2003). As stated previously, the presence of a developmental delay often coincides with varying degrees of impairment within both domains simultaneously (Hill, 1998; Owen & McKinlay, 1997; Waber et al., 2000; Webster et al., 2005). The simultaneous impairment of skills often acquired through motor learning and early language development further emphasizes the motor-language relationship through embodied cognition.

Current Measurement Tools

Standardized assessments are frequently used to measure and describe the motor skills of children with developmental delays. Many of the norm-referenced measures are based on the abilities of typically developing children. For children with developmental delays, this can be an issue because small changes in their abilities may not highlight a significant change on an assessment. Such small changes may be meaningful to the progression of their overall development and quality of life. Recently, many revisions of these assessments have included supplementary norm-referenced samples, using children with various disorders (Folio & Fewell, 2000; Sparrow, Balla, & Cicchetti, 1984). Additionally, motor tasks used in physical or occupational therapy have been integrated into the item content of standardized measures (Wilson, Wilson, Iacoviello, & Risucci, 1982). Researchers and clinicians assessing the motor abilities of children with disabilities often report raw scores rather than standardized scores to better describe a child's abilities. Raw scores allow for an item-by-item detailed understanding of an individual's capabilities, whereas standard scores often categorize all children with developmental delays into a single, poor performing category. Five assessments were commonly referenced throughout the literature when evaluating the motor abilities of young children with developmental delays. *The Battelle Developmental Inventory* (BDI; Berls & McEwen, 1999; Snyder & Lawson, 1993), the *Ages and Stages Questionnaire* (ASQ-3; Squire, Twombly, Bricker, & Potter, 2009), the *Mullen Scales of Early Learning* (MSEL; Mullen, 1995), the *Peabody Developmental Motor Scales-2* (PDMS-2; Folio & Fewell, 2000), and the *Vineland Adaptive Behavior Scales* (VABS; Sparrow et al., 1984) are all standardized assessments used to identify infants at risk for developmental delay, aid in assigning proper early intervention services, and assesses the efficacy of currently used interventions. Table 1 below provides a brief comparison of the assessments listed above.

Table 1.

Current Measure of Motor Ability Summaries.

Test	Age Range	Motor Subscales	Method of Measurement
BDI	Birth-8 years	Muscle control, coordination, locomotion, & perceptual motor abilities	Task performance, parent report & observation
ASQ-3	3 months- 5 years	Arm, trunk, leg, & finger movements	Parent report
PDMS-2	Birth-5 years	Individual Reflexes, Stationary, Locomotion, Object Manipulation, Grasping, & Visual-Motor Integration.	Observation & task performance
VABS	Birth-18 years (or adult with a mild intellectual disability)	Arm and leg coordination & object manipulation using hands and fingers	Parent report
MSEL	Birth- 5 years, 8 months	Mobility, central motor control, & visual discrimination	Task performance

Note. BDI: Battelle Developmental Inventory; ASQ-3: Ages & Stages Questionnaire-Third Edition; PDMS-2: Peabody Developmental Motor Scales-Second Edition; MSEL: Mullen Scales of Early Learning; VABS: Vineland Adaptive Behavior Scales.

The ASQ-3, BDI, MSEL, and VABS all have cognitive, social, communication, and language domains that overlap in the abilities they measure. However, there is fewer overlap in the item content when looking at the motor subscales. For example, the motor subscale of the BDI examines muscle control, body coordination, locomotion, fine muscle control, and perceptual motor abilities (Sattler, 2002). Whereas, the ASQ-3 questionnaire contains fine and gross motor items that ask caregivers about issues pertaining to their child's overall use of his or her arm, body, leg, and finger movements (Squires et al., 2009). The lack of overlap provides the examiner varying levels of detail concerning a child's motor capabilities. Even when there is more overlap between motor subscales, such as between the MSEL and the VABS, the method of measurement is different; therefore, providing another opportunity for the examiner to collect a variety of data on an individual's motor abilities that may not have been observed using a single method. Lastly, the PDMS-2 (Folio & Fewell, 2000) is a screening tool that measures motor capabilities and is divided into individual subscales that are only individual items on the ASQ-3, BDI, MSEL, and VABS.

The assessments mentioned use a range of methods, sources of information, and areas of examination when measuring a child's motor capabilities. The combination of two or more assessments when examining a child's motor skills is a common practice amongst investigators (Provost, et al., 2007a; Romski et al., 2010; Waber et al., 2000; Wuang et al., 2008) and widens the range motor constructs examined. Using multiple assessments simultaneously provides more information because conclusions are not solely derived from a single source. The conclusions derived from a parent-report-only measure may be different than those gained from an observational or experimental assessment. The increased amount of information available concerning the motor abilities of children with developmental delays may provide more support when identifying the most appropriate early intervention program.

Augmentative and Alternative Communication (AAC) Language Interventions

An intervention approach that may actually target both motor and language issues is an AAC language intervention. AAC is defined as the required knowledge, skills, and responsibilities when providing AAC services. AAC is a system that improves the functionality and effectiveness of an individual's ability to communicate by augmenting speech with aided or unaided symbols (American Speech-Language-Hearing Association, 2002). Children are given more opportunities to communicate with other people, resulting in long-term social and educational inclusion, independence, reduction in problem behaviors, and increased selfdetermination (Beukelman & Mirenda, 2005; Romski & Sevcik, 1997; Romski et al., 2010). Often children who do not have the physical means to communicate use AAC; however, children who do have those motor capabilities may experience an increase in motor learning as a result of the repetitive practice of directly selecting an SGD symbol during an AAC language intervention.

Romski et al. (2010) compared the language performance of 62 toddlers with developmental disabilities randomly assigned to one of three parent-coached augmented and non-augmented language interventions: Augmented Communication-Input (AC-I), Augmented Communication-Output (AC-O), or Spoken Communication (SC). In AC-I language intervention, the child was given spoken and augmented input by verbally modeling spoken words and modeling augmented words through use of the SGD to encourage communication without requiring the child to use a symbol. In AC-O language intervention, the child was required to use the SGD through verbal, visual, and physical hand-over-hand prompting from the parent or interventionist to produce augmented or spoken words. In SC language intervention, the child was visually and verbally prompted by the parent or interventionist to produce spoken words. The SC language intervention was modeled after a traditional spoken language intervention and participants assigned to this intervention did not have access to a SGD for communication. Appendix B provides a description of each intervention.

As described in Romski et al. (2010), the intervention consisted of 24 sessions, 18 in the laboratory and 6 at the child's home. Each intervention session lasted 30 minutes and was divided into three 10-minute routines of play, book, and snack. Each week, parents received a protocol manual that contained intervention goals for the parent, child, and interventionist. Parent coaching by the interventionist occurred throughout the entire intervention, and included general coaching of communication strategies and coaching strategies specific to implementing the intervention. During the first 8 intervention sessions, parents observed interventionists implement the intervention protocols in reference to their child's assigned intervention and were guided through each session by the managing speech language pathologist (SLP). From the 9th intervention session, parents were able to implement the intervention protocols starting at the snack routine of the intervention session. They were gradually worked into the other two intervention routines as more sessions were completed. By the 16th session, the parent had conducted the entire intervention session in the laboratory. The remaining intervention sessions were conducted at the child's home.

A list of target vocabulary words for the play, book, and snack routines of the intervention were created for each child by the project's managing SLP and the child's parent. The majority of the target vocabulary words were objects or actions appropriate for each routine of the intervention, such as ball, book, and cup. Additional target vocabulary words were functional terms and phases that were applicable across the three intervention routines, for example my turn, open, and all done. Target vocabulary was presented as an augmented and/or spoken word depending on the intervention a child was assigned. If a child mastered the initial set of target vocabulary words for any of the intervention routines, additional words were added to the child's vocabulary list through the collaborative effort of the project managing SLP, interventionist, and the child's parent. Results of the study demonstrated that participation in the augmented language intervention groups improved the vocabularies and communicative abilities of children with developmental delays. Between the two augmented conditions, children in the AC-O group used more target vocabulary words and were more likely to produce a spoken word. See Romski et al. (2010) for a complete description of the intervention and the observed outcomes. In summary, an AAC language intervention that utilizes a SGD creates a language-learning environment by improving a child's vocabulary, communicative opportunities, and the child-parent relationship.

Although communication is the primary goal of AAC, motor learning may be facilitated every time a SGD symbol is activated. Edward Thorndike's learning theory of connectionism (Throndike, 1911) contained multiple principles that illustrated the motor learning components of the AAC language interventions described in the Romski et al. (2010) study. All of the participants had the upper-body gross motor skills required to directly select symbols on the SGD and were provided with support for other available gross motor abilities. Both of those participant and intervention characteristics encompassed Thorndike's law of readiness, meaning the environment surrounding the child was conducive to active motor learning. Another aspect of the interventions, such as intervention dosage, was related to his law of exercise and general learning theory. Because participants met twice a week for 12 weeks, they practiced a specific motor skill repeatedly (i.e. law of exercise) under the favorable conditions provided by the parent or interventionist to strengthen that connection (i.e. law of effect). Lastly, Thorndike's learning principles of motivation and specific learned connections were represented throughout the intervention by connecting a child's wants or needs through the use of the SGD, and attempting to generalize the language interventions from the laboratory to the child's home (Oxendine, 1968). Overall, the combination of the communicative goal of AAC and the possible motor learning component of an augmented language intervention may grant the opportunity to begin to describe the motor skills of children with developmental delays before and after participation in a non-augmented and one of two augmented language interventions.

Research Questions and Hypotheses

The current study combined the use of standardized and observable measures collected as part of a larger, longitudinal study by Romski et al. (2010) to describe the motor abilities of toddlers with developmental delays who were participating in a non-augmented (i.e. Spoken Communication, SC) or one of two augmented language interventions (i.e. Augmented Communication-Input, AC-I; or Augmented Communication-Output, AC-O). Toddlers participating in the SC non-augmented language intervention were included in research questions 1 and 4 to serve as a control group. Because the SC language intervention was modeled after a traditional spoken language intervention, the suggested motor-language relationship was examined for the SC language intervention without the additional motor learning opportunities provided through the use of the SGD. The following questions were addressed:

1) What motor skills do toddlers with developmental delays who are not speaking have when they began one of three non-augmented or augmented language interventions? It was expected that the motor skills that toddlers with developmental delays bring to the intervention would be delayed across all of the language interventions as compared to typically developing children.

2) What is the relationship between the motor skills that the toddlers in the two augmented language interventions had prior to the start of the intervention and the upper-body, gross and fine motor skills observed during the 1st intervention session? It was hypothesized that the motor skills measured at pre-intervention using the *Mullen Scales of Early Learning*, *Vineland Adaptive Behavior Scales*, and *MacArthur-Bates Communicative Development*

Inventory would be significantly related to the upper-body, gross and fine motor skills coded during the 1st intervention session.

3) What are the differences across the two augmented language interventions in upper-body, gross and fine motor skills of toddlers with developmental delays observed during the 1st and 24th intervention sessions? It was expected that the toddlers who received the AC-I and AC-O language interventions would both show a decrease in physical prompting, an increase in spontaneous SGD activations, and an increase in developmentally appropriate motor skills from the 1st to 24th intervention session due to a child's interaction with the SGD. The toddlers who received the AC-O language intervention are expected to show a larger increase in developmentally appropriate motor skills, as compared to toddlers who received the AC-I language intervention because of the increased motor demands placed on the children when they used the SGD.

4) What is the relationship between the change in motor skills observed during the 1st to 24th intervention sessions and the language outcomes of the non-augmented and augmented interventions measured at the 24th intervention session? It was hypothesized that a change in motor skills over the course of the intervention would predict an increase in overall augmented and spoken word use. It was also expected that this relationship would be the strongest for the toddlers in the AC-O language intervention.

Methods

Participants

The sixty-two participants of the current study were part of the larger language intervention study conducted by Romski et al. (2010). Two of the participants were not included in the analyses that used event-coded observations due to damaged videotapes; therefore, for the analyses of questions 2 through 4, the total sample size was 60. Romski et al. (2010) randomly assigned participants to the non-augmented or augmented language interventions: Spoken Communication (SC), Augmented Communication-Input (AC-I), and Augmented Communication-Output (AC-O). As described in Romski et al. (2010), participants (mean age= 29.50 months) were recruited from various local sources, such as speech-language pathologists, developmental pediatricians, pediatric neurologists, and child advocacy groups across the metropolitan Atlanta area. Forty percent of parents reported that participants were receiving either occupational therapy or physical therapy at the beginning of the intervention. Table 2 provides the participants' pre-intervention demographic information.

To qualify as a participant, children were within the 24 to 36 months age range; had a risk for speech and language impairment, which was operationally defined as not having begun to talk (i.e. spoke no more than 10 intelligible words and received a score of less than 12 months of age on the Expressive Language scale of the *Mullen Scales of Early Learning*); exhibited at least a primitive attempt to communicate; had the ability to touch symbols on the SGD using upper body gross motor skills; did not have a diagnosis of delayed speech or language impairment, deafness/hearing impairment, or autism alone; and only spoke English at home. Interested parents contacted the project's principal investigator and managing SLP to schedule an appointment to discuss their possible participation in the study (Romski et al., 2010).

Table 2.

Participant Pre-Intervention Demographic Information.

Demographic Variables	Intervention Group AC-I (n=21)	AC-O (n=20)	SC (n=21)	Total (N=62)
Age (in months)	29	30	29	29
Gender				
Male	16	13	14	43
Female	5	7	7	19
Racial Background				
Caucasian	13	14	10	37
African-American	6	4	8	18
Asian	2	2	3	7
Receiving OT or PT	9	10	6	25

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output; SC: Spoken Communication; OT: Occupational Therapy; PT: Physical Therapy.

[a]Table adapted from Romski et al. (2010).

Intervention

Motor support and learning components of the intervention. In order to directly select a symbol and activate the SGD, participants had to complete the following actions: 1) extend their arm to cover the distance between themselves and the device and 2) manipulate their hand to directly select a symbol. Participants in both augmented language interventions had the upper-body gross motor skills that permitted them to directly select symbols on the SGD, as determined at the onset of the study. Beukelman and Mirenda (2005) noted that supportive seating and a stable flat surface provided a means for an individual to position themselves comfortably, involved the simultaneous proper positioning of multiple body parts, and was vital when using AAC. The lack of available motor support may decrease the efficiency of the upper-body gross motor skills the participants already possessed. The interventions made gross motor support available, specifically postural, trunk and balance support, by providing soft, comfortable and solid supportive seating options to accommodate any physical disabilities of the participants. Those supports allowed the participants to use their available upper-body gross motor skills during the entire intervention.

Measures

Mullen Scales of Early Learning (MSEL; Mullen, 1995) and Vineland Adaptive Behavior Scales (VABS; Sparrow et al., 1984). As part of the pre-intervention assessment, the MSEL and VABS were given to participants at baseline during the Romski et al. (2010) study to describe their language, visual, socialization, motor, maladaptive behaviors and daily living skills. Both assessments were briefly reviewed in the literature review. Raw and standard scores were computed for all of the individual subscales on the MSEL. Similarly, raw and age-equivalent scores were computed for each of the VABS subscales. Eighty-eight percent of the participants' MSEL composite standard scores were more than one standard deviation below the mean (Mullen, 1995). Romski et al. (2010) found no mean differences found across intervention conditions for age, visual reception, and language subscale measures at pre-intervention. Table 3 provides the MSEL and VABS pre-intervention raw and standard scores for each intervention group.

Table 3.

Participant Pre-Intervention Mean Raw and Standard Scores on the Mullen Scales of Early Learning and Vineland Adaptive Behavior Scales.

	Intervention Group							
	AC-I (*n*=21)		AC-O (*n*=20)		SC (*n*=21)		Total (N=62)	
Standardized Assessments	Raw	SS	Raw	SS	Raw	SS	Raw	SS
MSEL Visual Reception	21.14 (4.74)	29.10 (12.09)	22.40 (6.57)	31.60 (15.12)	22.81 (7.24)	31.90 (14.89)	22.11 (6.20)	30.85 (14.04)
MSEL Receptive Language	17.48 (5.70)	28.48 (13.76)	18.35 (6.29)	28.55 (12.34)	17.19 (6.70)	26.71 (12.00)	17.66 (6.16)	27.90 (12.55)
MSEL Expressive Language	11.52 (4.13)	22.43 (5.10)	12.85 (3.25)	21.85 (4.55)	11.24 (2.90)	21.00 (3.15)	11.85 (3.48)	21.76 (4.31)
MSEL Composite	__	60.14 (15.08)	__	58.70 (12.91)	__	59.10 (12.14)	__	59.32 (12.19)
VABS Receptive Age	16.33 (4.15)	17.86 (6.46)	17.00 (3.70)	18.25 (5.18)	16.71 (3.72)	18.00 (5.74)	16.68 (3.81)	18.03 (5.73)
VABS Expressive Age	9.33 (3.10)	12.67 (2.83)	9.45 (3.35)	12.60 (1.82)	8.71 (1.65)	12.62 (1.96)	9.16 (2.77)	12.63 (2.22)
VABS Composite	__	65.19 (9.13)	__	64.45 (7.64)	__	65.62 (6.44)	__	65.10 (7.70)

Note. Raw: Raw scores; SS: Standard scores; AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output; SC: Spoken Communication; MSEL: Mullen Scales of Early Learning; VABS: Vineland Adaptive Behavior Scales.

[a]Table adapted from Romski et al. (2010).

[b]Raw composite scores for the MSEL and VABS are not calculated for either test.

MacArther-Bates Communicative Development Inventories: Actions and Gestures (CDI; Fenson et al., 2007). Divided into five domains and totaling 63 items, the CDI measures a range of early communicative and representational gestures that do not require spoken language skills. The Actions and Gestures sections of the CDI were used for this study. The Actions and Gestures sections are useful for measuring early communication skills for children with expressive language delays. Raw scores on the First Communicative Gestures and Games and Routines sections were combined to create an Early Gestures raw score. Many of these items are vital to spoken communication development and are also foundational motor skills (e.g. pointing, reaching, or shaking or nodding the head). Raw scores on the last three domains, Actions with Objects, Pretending to be a Parent, and Imitating Other Adult Actions, complete the Later Gestures raw score. These three domains include symbolic and communicative gestures that emerge as a child ages. Items also include various fine and gross motor skills that evolve out of the most basic motor skills and require the integration of multiple motor skills for these complex movements to be completed (e.g. dancing, combing or brushing their hair, throwing a ball, or imitating sweeping with a broom or mop). A Total Gestures raw score was computed and is the summation of the Early and Later Gestures raw scores (Fenson et al., 2007). A standard score is not computed for the CDI. This assessment was given at baseline and at the completion of the intervention in the Romski et al. (2010) study.

Coding Schemes and Coding

Event-based observations were coded using the videotapes from the 1st and 24th intervention sessions to describe the communicative mode and motor skills employed by the participants. Five coding schemes, including one used in the Romski et al. (2010) study, captured the spoken and/or augmented word use, and the gross and fine motor skills used by the toddlers to interact with the SGD. Two codes from the reliable *Target Words* event-coding scheme by Romski et al. (2010) was used to capture the total spontaneous spoken or augmented word use. The *Symbol Activation* event-coding scheme included four categories of codes to describe the broad to specific motor methods used by participants to activate a symbol on an SGD: (a) *Type of Prompting*, (b) *Symbol Activation Errors*, (c) *Gross Motor*, and (d) *Fine Motor*. Operational definitions for each code are found below in Table 4.

Table 4.

Target Word and Symbol Activation Coding Scheme Definitions.

Code	Definition
	Target Word Coding Scheme[a]
Augmented Word Use	Child spontaneously employs an augmented vocabulary word through use of a SGD symbol to communicate.
Spoken Word Use	Child spontaneously employs an intelligible spoken vocabulary word to communicate.
Augmented & Spoken Word Use	Child spontaneously employs an augmented & intelligible spoken vocabulary word to communicate.
	Symbol Activation Coding Scheme
Prompting	
Activation After Hand of Hand Prompting	Child spontaneously employs both gross and fine motor skills to activate a SGD symbol immediately (i.e. within 3 seconds) after physical hand-over-hand prompted by the parent or interventionist. This code is specific to the AC-O language intervention due to the requirement of using the SGD.
Activation with No Prompting	Child spontaneously employs both gross and fine motor skills to activate a SGD symbol without being physical prompted by the

	parent or interventionist.
Symbol Activation Errors	
Complete Activation	Child spontaneously employs both gross and fine motor skills to activate a SGD symbol that results in a computer-generated word being produced. No activation errors were observed.
Minus Sound Activation	Child spontaneously employs both gross and fine motor skills to activate a SGD symbol; however, a computer-generated word is not produced.
Blank Symbol Activation	Child spontaneously employs both gross and fine motor skills to activate a blank symbol that did not have a symbol present; thus, not producing a computer-generated word.
Gross Motor	
Continuous Arm Extension	Several motor movements are strung together temporally close so that it creates a single smooth and continuous arm extension to cover the distance between the child and the SGD.
Discontinuous Arm Extension	Separate and distinct motor actions occur and create a sequence of rough movements that resemble a single arm extension to cover the distance between the child and the SGD.
Fine Motor	
Finger Pointing	Child uses one to all five fingers on one hand to activate a SGD symbol.
Open Hand/ Palm	Child uses the open flat surface of one hand to touch a SGD symbol.
Closed Fist	Child uses a single closed fist to activate a SGD symbol.
Thumb	Child uses a single thumb on one hand to activate a SGD symbol.

Other-Toy/Other Limb	Any additional spontaneous, intentional method that the child employs with an upper-body part or object to activate a SGD symbol. A child's intentions can be supported if the child uses the upper body part or object as an extension of their hand to access a symbol. Accidental SGD symbol activations completed by way of an object will not be coded.

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[a] The *Target Words* coding scheme section of Appendix C was adapted from Romski et al. (2010). Only a portion of the Target Words coding scheme was used for this study. The manual sign component of the Target Words coding scheme was not used for this study.

Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1985) transcripts of the 18th and 24th language intervention sessions were created during the Romski et al. (2010) study. The 24th language intervention session SALT transcripts from the Romski et al. (2010) study were used for this study as a guide during the coding process. The first step in the coding process was to denote the time and intervention routine in which the single event took place (i.e. play, book, or snack). Using the *Target Words* coding scheme, if the communicative mode was a spontaneous intelligible spoken word, then the occurrence of the single event was coded. If the communicative mode was either augmented word use or the combination of both spoken and augmented word use, the occurrence of that event was coded and the *Symbol Activation* coding scheme was used in a hierarchical manner.

Next, the *Type of Prompting* was coded, followed by the *Type Symbol Activation Errors*. The third step was to categorize the specific *Gross Motor* and *Fine Motor* movements the participants used. The proportion of augmented word, spoken word, and/or combined spoken/augmented word production by participants in the AC-I, AC-O, or SC language interventions during the 1st and 24th intervention sessions was calculated. The frequency of prompting type, type of spontaneous symbol activation, discontinuous or continuous gross motor arm extensions, and fine motor manual movements were calculated for both the AC-I or AC-O language interventions.

Reliability. The primary rater, the primary investigator, was not masked to the study's questions of interest; however, a secondary rater (undergraduate student) was masked to both of the study's questions and hypotheses. The primary rater coded both of the 1st and 24th intervention sessions for all 41 participants randomly assigned to either the AC-I or AC-O language interventions. The secondary rater coded 20% of the 1st or 24th language intervention sessions randomly selected using the RanSL program (Bakeman, 1999) for both AC-I and AC-O language interventions. The secondary rater was trained to a 90% agreement standard over 3 training sessions using the videotaped intervention sessions of participants who did not complete the intervention.

The reliability of the coding schemes developed for this study was assessed using 20% (8) of the randomly selected 1st or 24th language intervention sessions. Reliability was assessed for both 1st and 24th intervention sessions in order to demonstrate consistency, despite using the transcripts from the 24th sessions as a guide during the coding process. Landis and Koch (1977) suggested that a kappa statistic ranging between 0.60-0.79 indicates substantial agreement, with anything greater than 0.80 indicating outstanding inter-rater reliability. The kappa statistics for the coding categories developed for this study (Type of Prompting, Type Symbol Activation Errors, Gross Motor, and Fine Motor) were within the substantial or outstanding agreement range for the 1st intervention session: >0.99, 0.75, >0.99, and 0.88. Reliability was also within the substantial or outstanding agreement range for the 24th intervention session: >0.99, 0.93, >0.99, and 0.88.

Results

Motor Skills at the Onset of the Language Intervention Study

While both standard and raw scores were computed for the MSEL and VABS; raw scores used for the current analysis. Raw scores provided an item-by-item understanding of a child's performance on an individual subscale, which in turn provided more detailed information concerning the participants' specific motor abilities prior to the language intervention. Furthermore, the use of raw scores provided a consistent comparison across multiple tests. Because standard scores are not be calculated for the CDI, the participants' performance on the assessment couldn't be compared to their performance on the MSEL and VABS. Additionally, only 48 of the 62 participants were within the age limit for the MSEL Gross Motor subscale to receive a standard score that could be used in the analyses. The use of raw scores obtained on the MSEL permitted the motor abilities of all of the participants to be assessed.

The motor skills the participants had prior to the beginning of the intervention in the Romski et al. (2010) study were measured using the MSEL Gross and Fine Motor subscales, the VABS Gross and Fine Motor subscales, and the Action and Gestures portion of the CDI. Table 5 lists the mean raw scores for each motor subscale across each language intervention. Individual items that participants were able to complete for all three standardized assessments were examined. Participants completed items on the MSEL and VABS Gross Motor subscale such as standing alone, walking with assistance or alone, and rolling or throwing a ball while sitting. Participants completed MSEL and VABS Fine Motor subscale items such as being able to use the pincer grip, transfer blocks in or out of a box, turn multiple pages of a book, and pushing or pulling a door to open it.

The Actions and Gestures section of the CDI is divided into 5 sections. Parents reported that the participants were often able to complete some of the items within the First Communicative Gestures, Actions with Objects, Pretending to be a Parent sections, and Imitating Other Adult Actions portions of the CDI. On the Communicative Gestures portion, toddlers were reported to often extend their arm to show or give you a toy, point using their arm and index finger, and wave goodbye. On the Actions with Objects section, toddlers were reported to often use a utensil to eat, drink from a cup with a lid, wipe their face, push a car/truck and throw a ball. Lastly on the Pretending to be a Parent and Imitating Other Adult Actions sections, toddlers were reported to often pretend to hug or kiss a doll, “read” a book by opening it and turning the pages, and play a instrument like a toy piano or drum. Overall, the participants were able to complete items on the three standardized assessments that measured motor ability that contained similar content.

Table 5.

Pre-Intervention Motor Raw Scores on the Mullen Scales of Early Learning, the Vineland Adaptive Behavior Scales, and the MacArthur-Bates Communication Inventory (standard deviations in parentheses).

	Intervention Group			
Standardized Assessments	AC-I (*n*=21)	AC-O (*n*=20)	SC (*n*=21)	Total (N=62)
MSEL Gross Motor	20.48 (4.99)	20.50 (5.844)	22.57 (5.06)	21.19 (5.31)
MSEL Fine Motor	19.90 (5.45)	19.30 (4.67)	21.14 (5.05)	20.13 (5.05)
VABS Gross Motor	19.62 (6.71)	19.90 (5.99)	20.19 (6.01)	19.90 (6.15)
VABS Fine Motor	12.05 (4.44)	10.80 (2.73)	11.43 (2.48)	11.44 (3.33)
CDI Total Gestures (out of 63)	30.75 (13.69)	34.45 (16.71)	31.10 (15.14)	32.00 (15.05)

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output; SC: Spoken Communication; MSEL: Mullen Scales of Early Learning; VABS: Vineland Adaptive Behavior Scales; CDI: MacArthur-Bates Communication Inventory.

The hypothesized mean differences between the participants' scores were examined using a one-way ANOVA. Their scores were also compared to the raw scores often obtained by typically developing toddlers using four paired-samples t-tests. The range of raw scores typically developing children were reported to obtain on the MSEL and VABS was calculated using the scores reported for the measure's standardization sample (Mullen, 1995; Sparrow et al., 1984). The mean of the MSEL raw score range for typically developing children was used for the analyses. Overall, there were no statistically significant mean differences across the language interventions on any of the motor subscales and the CDI; however, the participants' raw scores were significantly lower as compared to scores often obtained by typically developing children. Figure 1 shows the participant's scores as compared to commonly reported scores of typically developing children on the MSEL and VABS. The mean scores reported for typically developing children were the average scores reported in the MSEL and VABS population standardization normed samples.

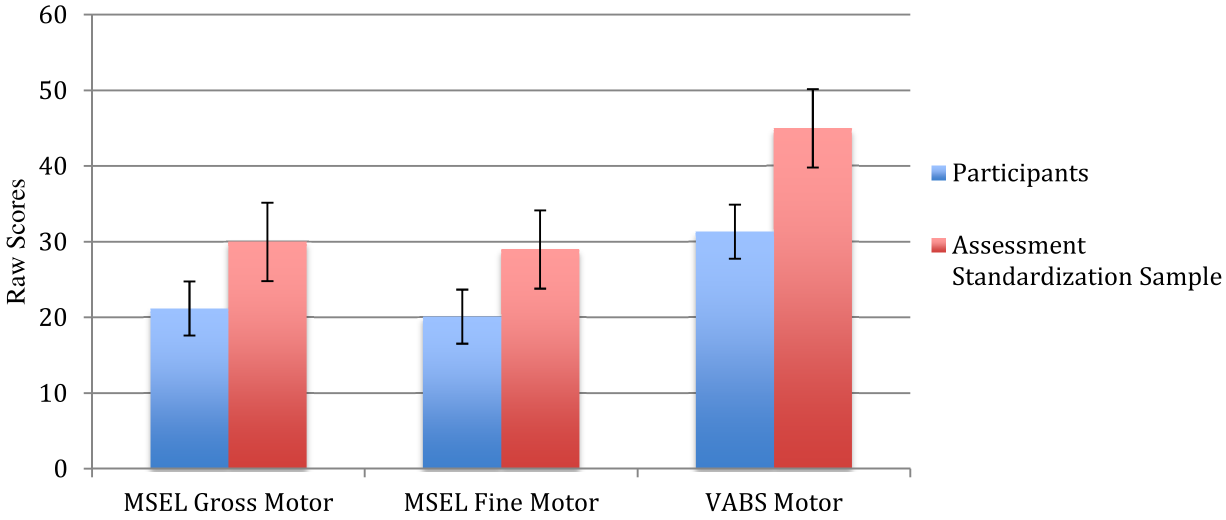

Figure 1. Comparison of the Participants' and Assessment Standardization Sample Mean Scores On the Mullen Scales of Early Learning and the Vineland Adaptive Behaviors Scales

On the MSEL, participants obtained a mean raw score of 21.19. (SD=5.31) and 20.13 (SD= 5.05) on the Gross and Fine Motor subscales, respectively. Typically developing children usually obtain a raw score within a mean score of 30 on the Gross Motor subscale and 29 on the Fine Motor subscale (Mullen, 1995). A one-sample t-test revealed that the mean raw score differences between the participants and typically developing children were statistically significant for the Gross Motor, $t(61) = -13.10$, $p<0.01$, 95% CI= -10.15 - -7.46 and Fine Motor subscale, $t(61) = -13.84$, $p<0.01$, 95% CI= -10.15 - -7.59. A similar pattern was observed on the VABS motor subscales. The participants obtained a combined gross and fine motor mean raw score of 31.34 (SD= 8.96). Typically developing children usually obtain a combined gross and fine motor raw mean score of 45 (Sparrow et al., 1984). A one-sample t-test revealed that the mean raw score difference for the participants and typically developing children was also statistically significant, $t(61) = -12.00$, $p<0.01$. Lastly, participants completed a mean of 32 (SD= 15.05) out of the 63 items that make up the Total Gestures raw score on the CDI. In other words, they were able to complete a little over half (50.79%) of the items on the Actions and Gestures section of the CDI.

The Relationship Between the Motor Skills Measured Using Standardized Assessments and Those Observed at the Onset of the Intervention

It was hypothesized that the gross and fine motor subscales of the MSEL, VABS, and CDI measured at pre-intervention would be significantly related to the gross and fine motor skills observed and coded at the 1st intervention session. The mean frequencies and standard deviations of the observed upper-body gross and fine motor skills observed during the 1st intervention session are reported in Table 6. A two-tailed Spearman's correlation coefficient (r_s) was used to provide additional descriptive information on the range of gross and fine motor skills being observed during the intervention in relation to the motor skills measured using the standardized assessments. Table 7 reports the Spearman's correlation coefficients for each correlation analysis completed.

Table 6.

Mean Frequencies of Observed Gross and Fine Motor Skills During the 1st Language Intervention Session (standard deviations in parentheses).

Observed Motor Skills	Mean Frequency
Gross Motor	
Discontinuous Arm Extension	2.41 (7.15)
Continuous Arm Extension	30.51 (28.61)
Fine Motor	
Finger Pointing	26.41 (27.79)
Open Hand/ Palm Use	3.07 (4.34)
Closed Fist Use	1.34 (6.88)
Thumb Pointing	2.59 (7.47)
Other	0.15 (0.42)

Table 7. *Spearman Correlation Coefficients Between the Observed Gross and Fine Motor Skills and the Mullen Scales of Early Learning, Vineland Adaptive Behavior Scales, and MacArthur-Bates Communicative Inventory at Pre-Intervention.*

	MSEL Gross Motor	VABS Gross Motor	MCDI Early Gestures	MCDI Later Gestures	MCDI Total Gestures	MSEL Fine Motor	VABS Fine Motor
Discontinuous Arm Extension	-0.08	-0.08	0.05	0.18	0.15	___	___
Continuous Arm Extension	0.13	0.11	0.25	0.18	0.21	___	___
Finger Pointing	___	___	0.31	0.23	0.27	0.35*	0.20
Open Palm	___	___	0.12	0.08	0.08	-0.10	0.08
Closed Fist	___	___	0.07	0.05	0.07	0.02	-0.03
Thumb Use	___	___	-0.14	-0.17	-0.18	0.03	0.20
Other	___	___	0.11	0.19	0.17	0.08	-006

Note. MSEL: Mullen Scales of Early Learning; VABS: Vineland Adaptive Behavior Scales; CDI: Mac-Arthur-Bates Communication Inventory

*p<0.05

Results of the correlation analysis indicated that the gross motor skills measured using the pre-intervention MSEL, VABS, and CDI scores were not significantly correlated to the gross motor behaviors observed during the 1st intervention session. The raw scores on the pre-intervention MSEL Fine Motor subscale had a significant, positive relationship with the coded finger pointing motor skill observed during the 1st language intervention session, r_s= 0.35, p< 0.05. The analysis also showed a trend towards a statistically significant, positive relationship between the pre-intervention CDI Early Gestures raw scores and finger pointing motor skill observed during the 1st language intervention session, r_s= 0.31, p= 0.05.

Does the Type of Language Intervention Differentially Influence the Gross and Fine Motor Skills Used to Activate a SGD?

The mean frequencies and standard deviations for prompting type, type of spontaneous symbol activation, gross motor arm extensions, and fine motor movements observed at the 1st and 24th intervention sessions are reported in Tables 8, 9, 10, and 11. Four sets of analyses were conducted to examine the multidimensionality of the hypothesized increase in motor skills from pre-intervention to post-intervention as the result of a child's interaction with a SGD.

Table 8.

Mean Frequency of Types of Prompting Required to Access a Symbol During the 1st and 24th Language Intervention Sessions (standard deviations in parentheses).

	1st Session: No Prompting	24th Session: No Prompting	1st Session: Physical Prompting	24th Session: Physical Prompting
AC-I (*n*=19)	27.90 (34.28)	25.90 (20.61)	—	—
AC-O (*n*=20)	39.50 (29.18)	60.50 (44.55)	2.55 (2.98)	1.05 (1.10)

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output.

[a] Mean frequencies for physical prompting for toddlers in the AC-I language intervention were not calculated because the intervention's protocol did not allow for the required use of the SGD via physical prompting.

Table 9.

Mean Frequency of Activation Errors During the 1st and 24th Language Intervention Sessions (standard deviations in parentheses).

	Complete Activations		Activation w/o Sound		Blank Activation	
	1st	24th	1st	24th	1st	24th
AC-I (*n*=19)	22.76 (28.16)	23.48 (20.79)	4.71 (6.73)	1.95 (2.34)	0.43 (1.96)	0.48 (1.03)
AC-O (*n*=20)	34.85 (28.56)	55.15 (44.61)	3.80 (5.10)	4.10 (4.95)	3.40 (7.27)	2.30 (4.32)

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output.

Table 10.

Mean Frequency of Gross Motor Arm Extensions Observed During the 1st and 24th Language Intervention Sessions (standard deviations in parentheses).

	Discontinuous Arm Extension		Continuous Arm Extension	
	1st	24th	1st	24th
AC-I (*n*=19)	1.62 (2.64)	2.29 (2.59)	25.48 (31.50)	19.71 (13.38)
AC-O (*n*=20)	3.25 (9.94)	4.95 (6.95)	35.80 (24.92)	56.15 (46.61)

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output.

Table 11.

Mean Frequency of Fine Motor Movements Observed During the 1st and 24th Language Intervention Sessions (standard deviations in parentheses).

	Finger Pointing		Open Hand		Closed Fist		Thumb		Other	
	1st	24th	1st	24th	1st	24th	1st	24th	1st	24th
AC-I	23.19	17.19	1.86	0.95	0.33	0.19	1.48	1.19	0.05	1.05
(*n*=19)	(31.94)	(13.37)	(2.92)	(2.06)	(0.97)	(0.68)	(4.68)	(4.81)	(0.22)	(2.18)
AC-O	29.80	52.45	4.35	2.40	2.40	1.45	3.75	11.45	0.25	1.05
(*n*=20)	(22.99)	(47.54)	(5.23)	(5.15)	(9.82)	(3.78)	(9.58)	(27.02)	(0.55)	(2.72)

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output.

The first analysis included a 2 X 2 Mixed ANOVA to examine group differences for symbol activations that did not require physical prompting. An interaction effect was found of intervention type and time when activations did not require physical prompting (See Figure 2). Participants in the AC-O language intervention significantly increased their augmented word use that did not require physical prompting as compared to toddlers in the AC-I language intervention across intervention sessions, $F(1,38)= 8.03$, $p<0.01$, partial $\eta^2=0.17$. A Within-Subjects ANOVA was also conducted to examine the hypothesized change in physically prompted symbol activations for participants in the AC-O language intervention. Due to their increase in augmented word use without prompting, toddlers in the AC-O language intervention significantly decreased their need for physical prompting during intervention sessions, $F(1,19)=$

4.48, $p<0.05$, partial $\eta^2=0.19$ (See Figure 3). Despite the decrease in physical prompting, toddlers in the AC-O language intervention often used developmentally appropriate gross and fine motor skills (i.e. employing both a continuous arm extension and finger pointing during a single event) immediately after being physically prompted to activate the SGD. The individually coded symbol activations were examined and 84.3% of the symbol activations occurring after physical prompting utilized both developmentally appropriate gross and fine motor skills.

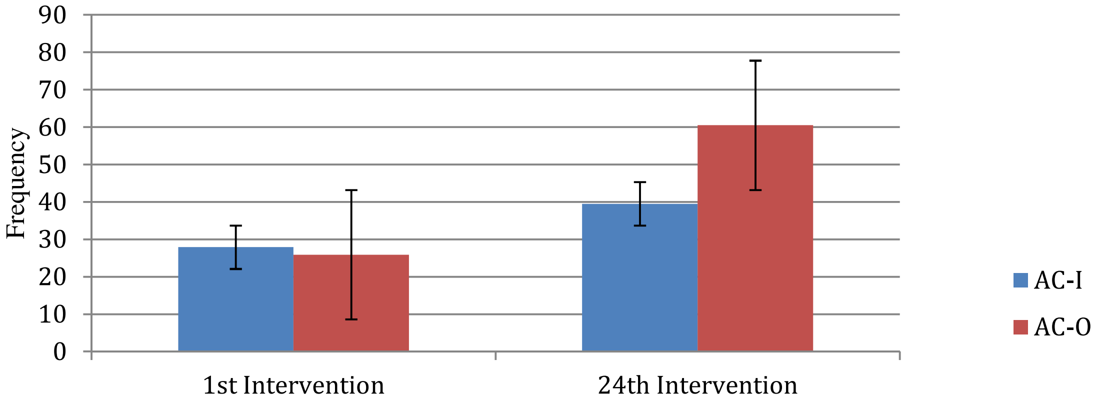

Figure 2. Interaction Effect of Intervention Type and Time for the Frequency of Observed SGD Symbol Activations Without Physical Prompting

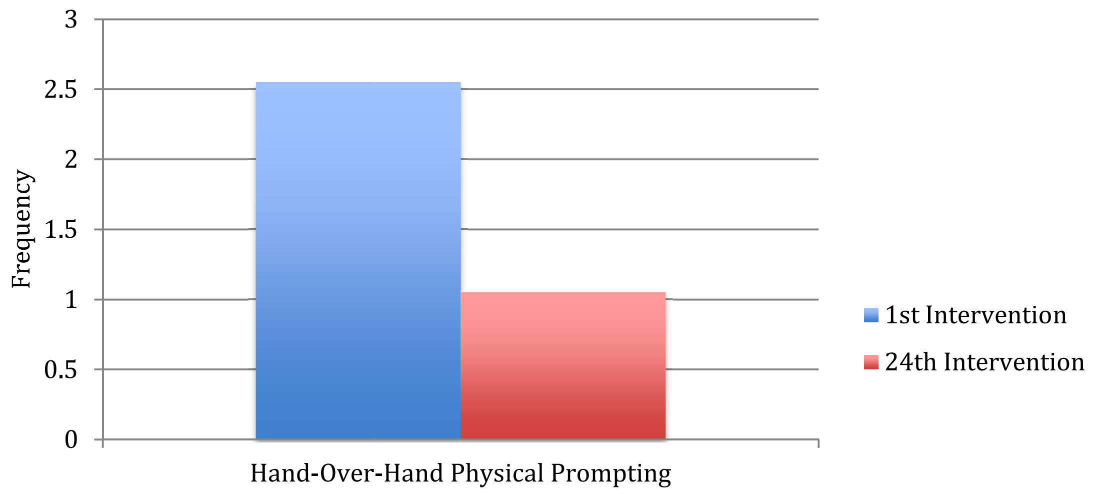

Figure 3. Frequency of Physical Promtping From the 1st to 24th Intervention Session for AC-O Participants.

The second analysis included three, 2 X 2 Mixed ANOVAs to examine group differences for the types of symbol activation errors participants were observed to make at the beginning and end of the intervention. Again, to account for the multiple simultaneous analyses, another Bonferroni correction was applied, adjusting the p-value to 0.016. There was a interaction effect of intervention type and time on the frequency of observed complete SGD symbol activations, $F(1,38)=8.13$, $p<0.01$, partial $\eta^2=0.17$ (See Figure 4). Participants in the AC-O language intervention were observed increasing the frequency of fully activating a SGD symbol without errors between the 1st and 24th intervention sessions as compared to those in the AC-I intervention. There were no significant effects of frequency of either SGD symbol activation minus the production of an augmented word or the activation of a blank SGD symbol (See Figures 5 & 6).

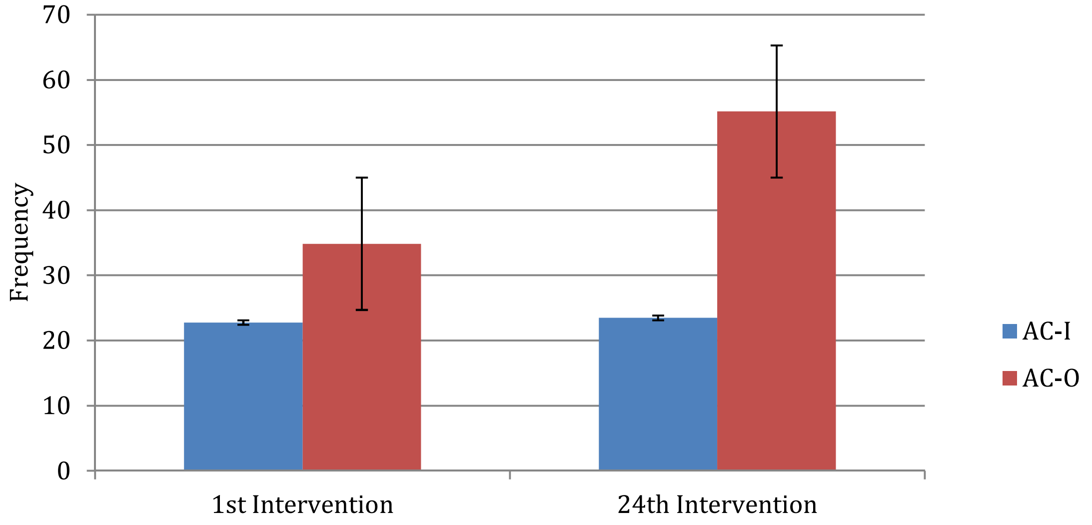

Figure 4. Interaction Effect of Intervention Type and Time for the Frequency of Complete SGD Symbol Activations

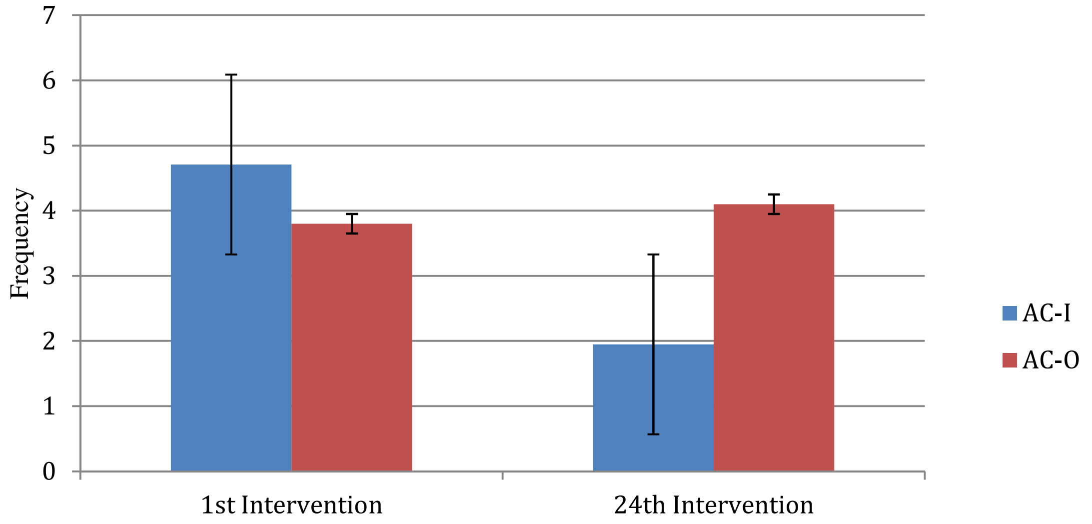

Figure 5. Frequency of SGD Symbol Actiovations Without an Augmented Word Produced.

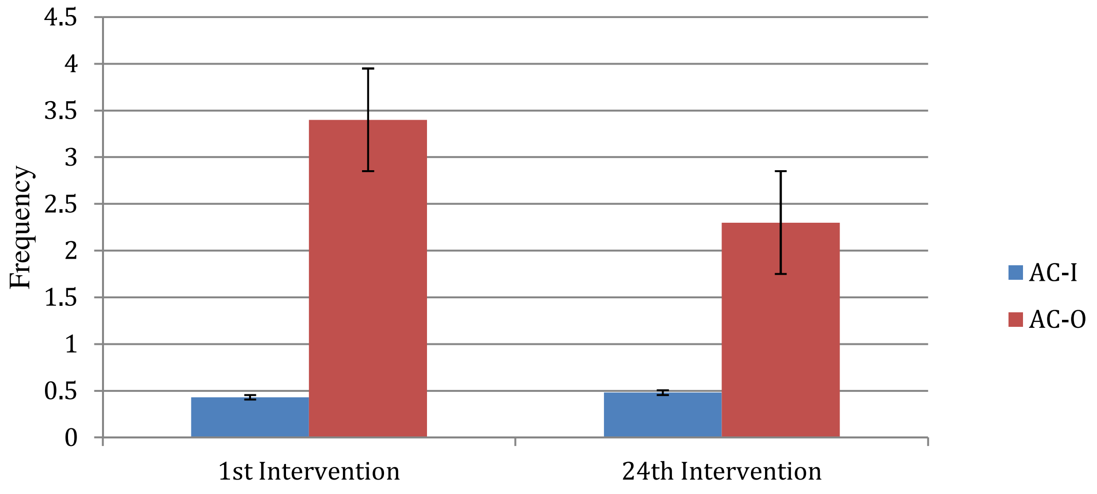

Figure 6. Frequency of Blank SGD Symbol Activations

The third analysis included two, 2 X 2 Mixed ANOVAs that examined group differences for the discontinuous and continuous gross motor arm extensions observed during the 1st and 24th intervention sessions. To account for the multiple simultaneous analyses, a Bonferroni correction was applied, adjusting the p-value to 0.025. The results indicated that there was not a significant main effect for either language intervention or frequency of observed discontinuous gross motor arm extensions (See Figure 7). There was a significant interaction effect of intervention type and time for the frequency of continuous gross motor arm extensions, $F(1,38)= 9.08$, $p<0.01$, partial $\eta^2= 0.19$. Toddlers in the AC-O language intervention were observed increasing their use of a continuous gross motor arm extension when accessing the SGD as compared to toddlers in the AC-I language intervention from the 1st to 24th session (See Figure 8).

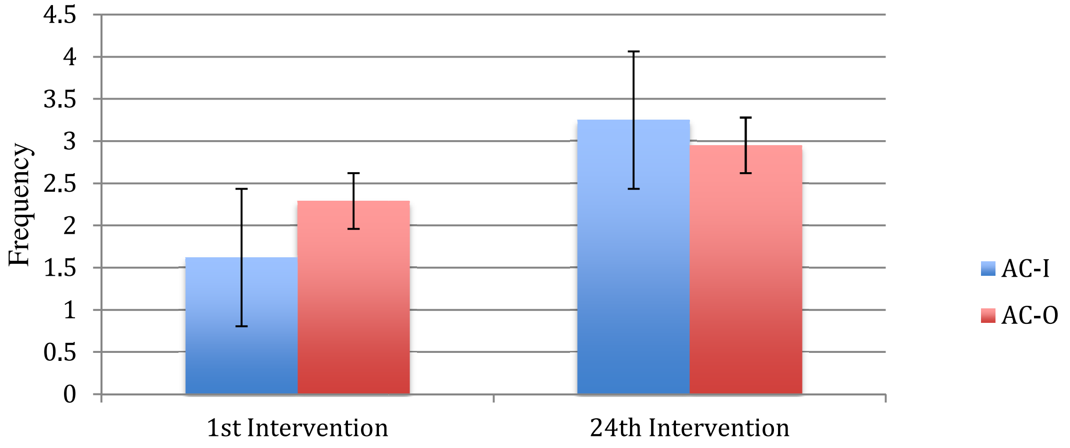

Figure 7. Frequency of Discontinuous Gross Motor Arm Extensions.

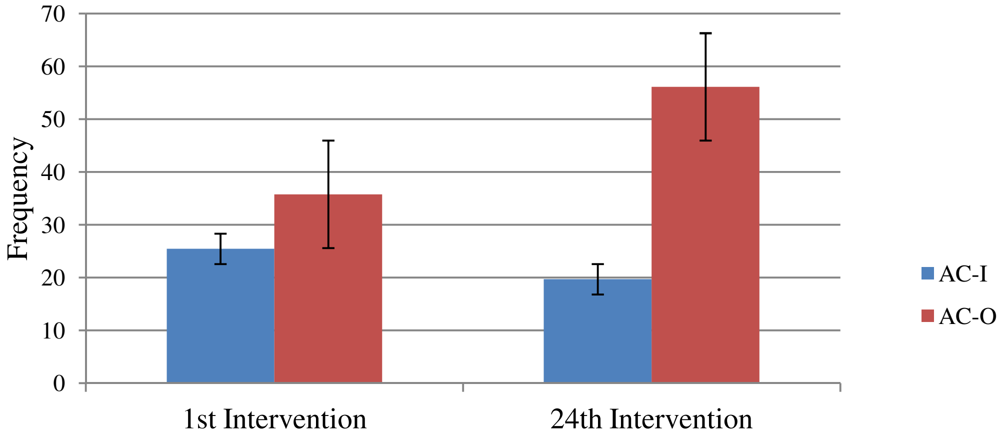

Figure 8. Frequency of Continuous Arm Extensions by Intervention.

The fourth analysis included five 2 X 2 Mixed ANOVAs to examine group differences in the fine motor movements observed during the 1st and 24th intervention sessions. To account for the multiple simultaneous analyses, a Bonferroni correction was applied, adjusting the p-value to 0.01. There were no significant effects for the open palm, closed fist, thumb, and other fine motor movements observed and coded during each intervention session (See Figure 9). The results only indicated a significant interaction effect for the fine motor skill of intervention type and time for finger pointing from the 1st to 24th intervention session, $F(1,38)= 7.21$, $p<0.01$, partial $\eta^2=0.16$ (See Figure 10). In other words, toddlers in the AC-O language intervention were observed increasing their use of their finger pointing fine motor skills when accessing the SGD as compared to toddlers in the AC-I language intervention across sessions.

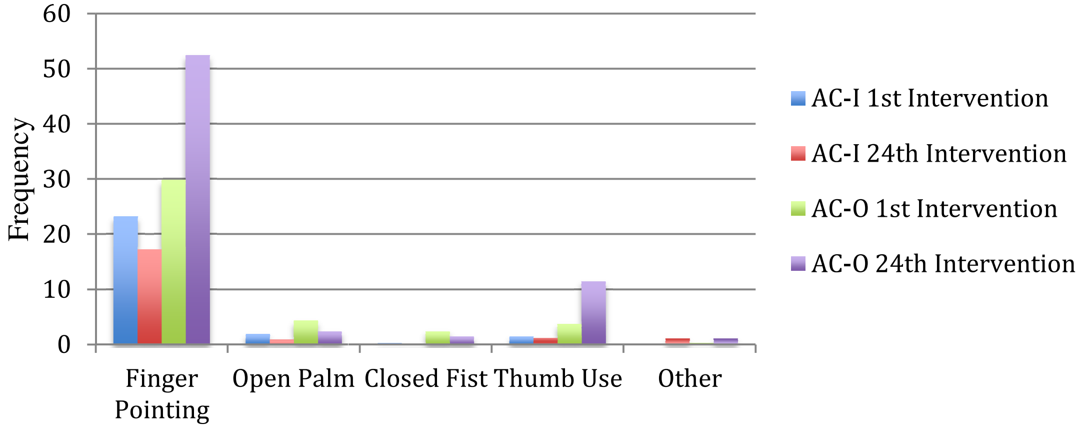

Figure 9. Frequency of Fine Motor Skills From the 1st to 24th Interventions

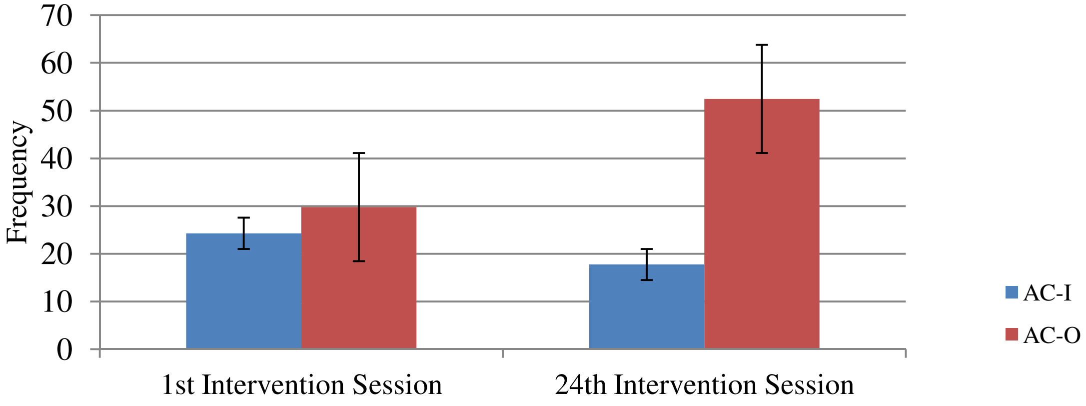

Figure 10. Intraction Effect of Intervention Type by Time for Finger Pointing Use

Does a Change In Motor Skills Predict the Language Outcomes of the Intervention?

The proportion of augmented word and spoken word use were two of the language outcomes collected and measured by Romski et al. (2010) during the 24th intervention session (See Table 12). The final set of analyses examined whether or not the change in motor skills over the course of the language intervention was significantly related to the language outcomes measured during the 24th intervention session. Four multiple regression analyses were conducted to test this relationship, controlling for the toddlers' participation in either physical or occupational therapy reported at pre-intervention by their parent. By controlling for reported participation in physical or occupational therapy, the unique effect of pre-post intervention CDI raw score difference and the combined developmentally appropriate motor skills (i.e. employing both continuous arm extension and finger pointing to access a SGD symbol) mean difference was examined.

Table 12.

Mean Proportion of Augmented Word and Spoken Word Use During the 24th Intervention Session by Intervention Group (standard deviations in parentheses).

Language Intervention Outcomes	AC-I (*n*=21)	AC-O (*n*=20)	SC (*n*=21)	Total (N=62)
Augmented Word Use	0.50 (0.25)	0.66 (0.26)	__	0.58 (0.27)
Spoken Word Use	0.21(0.23)	0.15 (0.13)	0.15 (0.14)	0.16 (0.16)

Note. AC-I: Augmented Communication-Input; AC-O: Augmented Communication-Output; SC: Spoken Communication.

[a] Table adapted from Romski et al. (2010).

[b] The proportion of augmented word use cannot be calculated for participants in the SC language intervention because the intervention does not utilize a SGD.

The first regression analysis examined the effect of the change in MCDI raw scores from the 1st to 24th intervention on the measured spoken word for toddlers only in the SC language intervention; however, no significant effects were found (See Table 13). The second regression analysis examined the effect of change in MCDI raw scores and frequency in developmentally appropriate gross and fine motor skills on the measure spoken word use for toddlers both augmented language interventions. The results showed a similar pattern as the SC participants, with no significant, unique effect of the change in motor skills on spoken word use (See Table 14).

Table 13.

Regression Model Predicting Spoken Word Use by Motor Skill Change for SC Language Intervention Participants.

	B	SE	β	p	95% CI
Receiving PT/OT	-0.11	0.05	-0.05	.84	-0.12 – 0.09
Receiving PT/OT	-0.02	0.06	-0.07	-0.77	-0.13 – 0.09

MCDI Raw Score Change	0.001	0.001	0.100	0.69	-0.001 – 0.002

Note. SC: Spoken Communication; PT: Physical Therapy; OT: Occupational Therapy; MCDI: MacArthur-Bates Communicative Inventory.

Table 14.

Regression Model Predicting Spoken Word Use by Motor Skill Change for AC-I and AC-O Language Interventions.

	B	SE	*β*	*p*	95% CI
Receiving PT/OT	-0.08	0.04	-0.28	0.07	-0.16 – 0.01
Receiving PT/OT	-0.08	0.04	-0.30	0.07	-0.17 – 0.01
Observed Motor Skill Change	0.00	0.00	0.07	0.70	-0.001 – 0.001
MCDI Raw Score Change	-0.001	0.001	-0.09	0.59	-0.003 – 0.002

Note. AC-I: Augmented Communication- Input; AC-O: Augmented Communication-Output; PT: Physical Therapy; OT: Occupational Therapy; MCDI: MacArthur-Bates Communicative Inventory.

The third regression analysis examined the effect of motor skill change on augmented word use and was also conducted using toddlers only assigned to one of the two the augmented language interventions. The results indicated a significant linear relationship between the independent variables and augmented word use during session 24, (R^2= 0.21, $F(3, 35)$= 3.01, p= 0.04). When controlling for participation in physical or occupational therapy, the regression model accounted for approximately 21% of the variance. The change in developmentally appropriate motor skills used was found to have a significant unique effect of predicting augmented word use, when controlling for the other predictors, B=0.06, SD=0.02, β=0.41,

$t(3,35)=2.60$, $p<0.05$, 95% $CI=0.01\text{-}0.10$. Thus, for every unit increase in the use of developmentally appropriate motor skills to access a SGD symbol, there was a predicted 0.06 unit increase in augmented word use (See Table 15).

Table 15.

Regression Model Predicting Augmented Word Use by Motor Skill Change for AC-I and AC-O Language Interventions.

	B	SE	β	*p*	95% CI
Receiving PT/OT	-4.05	2.89	-0.23	0.17	-9.89 – 1.80
Receiving PT/OT	-4.70	2.75	-0.26	0.09	-10.29 – 0.88
Observed Motor Skill Change	0.06	0.02	0.41	0.01*	0.01 – 0.10
MCDI Raw Score Change	-0.11	0.08	-0.21	0.20	-0.28 – 0.06

Note. AC-I: Augmented Communication- Input; AC-O: Augmented Communication-Output; PT: Physical Therapy; OT: Occupational Therapy; MCDI: MacArthur-Bates Communicative Inventory.

As discussed in the previous analyses, toddlers in the AC-O language intervention were observed increasing their use of developmentally appropriate motor skills from the onset to the conclusion of the intervention. Similarly for participants only in the AC-O language intervention, the regression model indicated a significant linear relationship between the independent variables and augmented use during session 24, ($R^2= 0.43$, $F(3,15)= 3.99$, $p= 0.03$). The change in the use of developmentally appropriate motor skills had a significant unique effect on predicting augmented word use, when controlling for occupational and/or physical therapy participation, B=0.07, SD=0.03, $\beta=0.50$, $t(1,18)=2.46$, $p<0.05$, 95% $CI=0.01\text{-}0.13$; thus, a single unit increase in developmentally appropriate motor skills use by toddlers in the AC-O language intervention indicated a 0.07 unit increase in augmented word use (See Table 16).

Table 16.

Regression Model Predicting Augmented Word Use by Motor Skill Change for AC-O Language Interventions.

	B	SE	*β*	*p*	95% CI
Receiving PT/OT	-5.00	4.44	-0.26	0.28	-14.34 – 4.34
Receiving PT/OT	-6.98	4.01	-0.36	0.10	-15.50 – 1.52
Observed Motor Skill Change	0.07	0.03	0.50	0.03*	0.01 – 0.13
MCDI Raw Score Change	-0.92	048	-0.37	0.07	-1.94 – 0.10

Note. AC-O: Augmented Communication-Output; PT: Physical Therapy; OT: Occupational Therapy; MCDI: MacArthur-Bates Communicative Inventory.

Discussion

The purpose of this study was to examine the effect of a non-augmented and one of two augmented language interventions on the measured language outcomes and motor skills of toddlers with developmental delays. The results confirmed that there was an effect for the AC-O language intervention on the frequency of augmented word use and the use of developmentally appropriate gross and fine motor skills when attempting to access a SGD symbol. Participants were observed to have delayed gross and fine motor skills as compared to typically developing children. These results support the initial hypothesis and replicate similar findings reported by numerous studies that young children with developmental delays are often observed with impaired motor skills, often more than 1 standard deviation below the mean (Mari, Castiello, Marks, Marraffa, & Prior, 2003; Mahoney, et al., 2001; Provost, Heimerl, & Lopez, 2007a; Provost, Lopez, Heimerl, 2007b; Shumway-Cook & Woollcott, 1985). For example, Deffeyes, Harbourne, Kyvelidou, Stuberg, and Stergiou (2009) identified a nonlinear measure that found poor motor control in infants at risk or diagnosed with cerebral palsy or a global delay, indicated by a pattern of sitting postural sway.

The results from the second analyses examining the relationship between the pre-intervention MSEL, VABS, and CDI motor scores and the event-coded motor skills was barely supported. It was hypothesized that the motor skills measured at pre-intervention using the MSEL, VABS, and CDI would be significantly related to the upper-body, gross and fine motor skills observed and coded during the 1st intervention session. The MSEL Fine Motor subscale score was only significantly related to one of the five fine motor skills observed, finger pointing. The content of the individual items on the MSEL and VABS Gross Motor subscales were examined. The majority of the items on the MSEL and VABS were not directly related to the skills required to access and directly select a SGD symbol. Test items on the MSEL and VABS motor subscales, and specific items on the CDI provided more of a global understanding of the participants' gross and fine motor capabilities.

Many of the motor tasks required the integration of multiple simple and complex motor skills that had not been mastered by participants prior to beginning the study. Only 4 out of 35 items on the MSEL and 2 out of 20 items on the VABS described the gross motor tasks that were similar to the gross motor requirements when a toddler attempted to cover the distance between themselves and the SGD. A similar pattern was found for the content of the fine motor subscales, with 8 out of 30 items on the MSEL and 3 out of 16 items on the VABS described the fine motor tasks that mimic the skills needed to directly select a SGD symbol. Lastly on the CDI, 10 out of the 63 items described the gross and fine motor skills needed to access the device. The low incidence of test items mapping onto motor movements used to activate a SGD symbol may provide a reason why a significant relationship was not observed. The use a of a standardized screening tool that focuses only on motor skills, such as the *Peabody Developmental Motor Scales-2* (PDMS-2), to measure motor ability may consist of more items that may map directly onto the skills required to access a SGD symbol.

The third set of analyses examined whether or not the type of intervention influenced the gross and fine motor skills used to access and directly select a SGD symbol. The first hypothesis was partially supported, with the expected results being observed only for the toddlers in the AC-O language intervention. The findings from the four sets of analyses also provided full support for the second hypothesis. The toddlers in the AC-O language intervention may have showed a larger increase in developmentally appropriate gross and fine motor skills because of the increased motor demands placed on the children when they used the SGD. Toddlers in the AC-O language intervention were required to use the SGD through verbal, visual, and physical hand-over-hand prompting from the parent or interventionist every time the child intended to produce an augmented word. The increased finger pointing used to activate a SGD symbol from the 1st to 24th intervention session may be linked to a possible increase in language comprehension, as reported by Butterworth and Morissette (1996) to be one of the primary functions of the behavior. Finger pointing often occurs with speech or a vocalization in typically developing children to indicate comprehension of shared interests; however, participants in the AC-O language intervention may have paired the finger pointing behavior with the utilization of the SGD to make their intentions known.

The repetitive direct selection of a SGD symbol provided the necessary motor learning opportunities for a specific motor skill when required to activate a SGD symbol. Thorndike's law of exercise supports the notion that the consistent practice of a specific responsive action to a stimulus would strengthen the association between the two actions (Oxendine, 1968; Thorndike, 1911); thus, the repetitive direct selection of SGD symbol as a response to the parent's or interventionist's prompts to communicate strengthened the connection. Another key principle to motor learning is motor adaptation, which allows the motor system to adjust to its default performance state after a separate, distinct action within a single context (Shadmehr & Wise, 2005). Therefore, it can be suggested that a participant's ability to effectively adjust the motor system between directly selecting a SGD symbol and another activity during an intervention routine was both acquired and fully controlled by the individual without interruption.

The frequency of prompting, activation errors, and use of developmentally appropriate gross and fine motor skills were consistent and did not significantly change over the course of the intervention for the participants in the AC-I language intervention. Even though they were not required to use the SGD to produce an augmented word, their consistent use of the device should have influenced a decrease in activation errors because they still had practice using the SGD to communicate. Again, the concept of motor adaptation may provide some understanding of these results. Because the motor system returns back to its default motor performance after an interaction with the device, a new skill is not acquired because the consistency in the frequency of motor behaviors is no more accurate than before the initial adaptation (Shadmehr & Wise, 2005). The AC-I language intervention protocol for the non-required use of the SGD did not strengthen or eliminate the connection between a SGD activation error and a parent or interventionist's response. The constant use of the observed gross and fine motor skills across the AC-O intervention permitted the child's motor system to return to its normal performance state once interacting with the device without any interruption to the child's current motor skill repertoire.

For the final analysis, it was hypothesized that a change in motor skills over the course of the intervention would predict an increase in overall augmented word and spoken word use. It was also expected that this relationship would be the strongest for the toddlers in the AC-O language intervention. The results of the final analysis partially supported the hypothesis. The change in CDI scores and use of developmentally appropriate motor skills only predicted augmented word use, but this effect was also stronger for toddlers in the AC-O language intervention as compared to toddlers in the AC-I language intervention.

The regression analyses showed that there was not a unique effect of the change in motor skill on spoken word use. A possible explanation is that language skill acquisition may not always follow the attainment of a new motor skill for children whose primary communicative mode is not speech. Bonvilian, Orlansky, and Novack (1983) examined the early sign language acquisition of 11 children with deaf parents in relation to the acquisition of developmental motor milestones. All of the children spoke and used sign language. Seven of the 11 participants were under the age of 1 year at the start of the study. The other 4 participants were 12 –months, 18-months, 2-years, and 3-years old. Two observers recorded each child's observed motor skills and expressive/receptive sign language during videotaped structured (3 minute play and communication sessions) and unstructured interactions with their parent. Instead of language acquisition occurring after the achievement of a motor milestone, 73% of the observed interactions showed that the number of signs from the previous month was greater than the number of motor milestones achieved. The researchers argued that the inability to find a similar pattern of language and motor skill acquisition as originally hypothesized may be a result of two events, differential maturation periods or sign language and motor milestones tap into only a small portion of motor learning shared by the two skill sets. An alternative pattern of language and motor skill acquisition observed may be pertinent to this study's participants because of their significant difficulty acquiring speech and current use of a SGD as their primary communicative mode.

These results lend further support to the increased effect of the intervention type when predicting augmented word use. Romski et al. (2010) found that the children in the AC-I language intervention had a significantly smaller augmented vocabulary size at the 24th intervention session, as compared to the participants in the AC-O language intervention. They argued that the augmented output intervention highlighted a link between the comprehension and production of augmented words. When considering language comprehension, production, and motor actions as tasks that require a certain amount of cognition, the concept of embodied cognition may provide further understanding into how the motor-language relationship was facilitated by the type of augmented intervention (Iverson & Braddock, 2011). The positive increase in CDI scores and use of developmentally appropriate gross and fine motor skills throughout the intervention may lend further support to the demonstration of the enhanced comprehension experienced by the toddlers in the AC-O language intervention.

Study Limitations

There were two primary limitations of this study that are related to conducting secondary analyses (McCall & Appelbaum, 1991): 1) Mismatch of focus between the original and current study and 2) Lack of control in the measures chosen. First, this study used data from the longitudinal study by Romski et al. (2010). The original data were collected for different research questions and primary purpose than this study; thus the primary focus of the data collected is different than the current study (McCall & Appelbaum, 1991). The communication between the child and parent or interventionist was the focus of the Romski et al. (2010) study; however, the gross and fine motor skills used by the child to access the device during the augmented language intervention sessions were the primary focus of this study. Despite the camera always being focused on both the child and parent during the original filming by Romski et al. (2010), the coders for this study were only focused on the child and SGD. The mismatch in focus between the two studies sometimes resulted in difficulty visualizing the device.

The second limitation of this study is the use of tests developed to measure a child's available motor skills and overall motor development. The PDMS-2 (Folio & Fewell, 2000) is a screening tool that uses experimental tasks and observations to measure motor ability. It also could be used to measure and identify the specific motor skills that are essential to the motor learning opportunities provided to toddlers when repeatedly accessing a SGD symbol; however, the PDMS-2 cannot be administered and scored correctly when collecting data with videotapes. It was only appropriate to describe the participants' motor skills using the available MSEL and VABS motor scores collected by Romski et al. (2010). The CDI was also used as a pre-post measure of motor abilities because of the various motor skills included in the test's items, despite its primary use being to measure communicative ability. Even though the motor subscales only provided a global measurement of motor ability, performance on those tests were combined with the detailed coded motor movements.

Clinical Implications & Future Research

The results of this study and future research concerning the motor-language relationship may be influential in the future applications of augmented language interventions that utilize a SGD. The repetitive use of the device through the requirements of the AC-O language intervention had a significant influence on the increased use of developmentally appropriate gross and fine motor skills. It also predicted future augmented word use. For young children having significant difficulty acquiring speech, the ability to communicate with others using AAC is essential to the possible facilitation of future spoken language (Romski & Sevcik, 1997). The physical and communication level observed during the interaction between the child and the device may tap into another domain of AAC language interventions that targets both language and motor impairments as part of the early intervention protocol. For children with delayed but functional motor skills, their available motor skills are often only used to determine their present communication level and deciding on the appropriate type of AAC intervention (Beukelman & Mirenda, 2005), leaving motor-sensory interventions to occupational and physical therapies. The motor learning opportunities that occur as part of AAC interventions are often overlooked and may be beneficial to both the child's overall development and the interactions with others.

As mentioned previously, one of the primary functions of finger pointing is comprehension (Butterworth & Morissette, 1996). The suggested enhanced comprehension of the participants in the AC-O language intervention may have been expressed through the increase in finger pointing observed during this study and the increased vocabulary measured by

Romski et al. (2010). The continuation of this line of research should examine the possible relationship between increased finger pointing and comprehension of toddlers participating in an augmented language intervention. Furthermore, the relationship between hand preference or lack there of, on the motor skill learning observed during the intervention should be examined. Morris and Romski (1993) found that the occurrence of ambiguous and left-hand preference of children with intellectual disabilities, with the lack of hand preference often being an indicator of the presence of a developmental disorder (Brakke et al., 2007). Understanding the strength and direction of the relationship between hand preference, finger pointing, and comprehension may provide further insight into the additional aspects of early language and motor development.

Future research should also move from coding the observed motor movements to using motion capturing technology to quantify and gain a more detailed understanding of the motor sequencing involved in directly selecting a device. Brakke et al. (2007) used the Peak Motus motion measurement system to collect the quantified kinematic data from videotape free-play bimanual cymbal banging and drumming for all qualifying bouts in typically developing toddlers. The participants in this study all had the ability to independently access the toys using their upper-body gross and fine motor skills. Detailed kinematic data on both the individual and aggregate group level would provide a deeper level of understanding of skills heavily involved in motor learning, skill acquisition, and overall motor development during AAC interventions. The collection of longitudinal kinematic data when a child directly selects a SGD symbol may contribute to the decision-making process of choosing and/or transitioning to a specific SGD for a child during the intervention.

Clinicians often use an assessment tool, such as the Communication Matrix, to determine the appropriate level of technology for a child (Beukelman & Mirenda, 2005; Rowland, 2004;

Rowland, 1996). However, these tools do not only focus on a single domain, such as motor or communicative skills, but combines multiple constructs both inter- and intra-individual domains for its recommendations. They also utilize a communication needs model to identify a child's needs and barriers in order to assess their current communicative skills. The kinematic data collected using a software similar to Peak Motus could also aid in the development of an assessment that would streamline a list of motor capabilities a young child must have for certain devices so that it could be used in a manner that would enhance the communicative and language outcomes of an augmented language intervention.

Conclusion

In conclusion, the requirements of the AC-O language intervention provided motor learning opportunities that permitted an increase in both gross and fine motor skills observed. The increase in the observed motor skills exhibited by the toddlers in the AC-O language intervention may also be linked to enhanced language comprehension skills. Although the pattern and type of relationship may differ as a result of communicative mode, these results support the suggested motor-language relationship. Further research should be conducted to examine the motor-language relationship longitudinally, across various types of AAC interventions, and multiple modes of communication, and diagnoses.

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Appendix A

Motor Skill Sequence of Typically Developing Children Between Two and Six Years of Age.

Age	Motor Skills

2 years	Runs well, walks up and down alone, kicks ball, stack 6-7 blocks, turn a page of a book.
2 ½ years	Attempts to stand on 1 foot, stacks 10 blocks, holds crayons with fingers.
3 years	Walks tip toe, stands on 1 foot, tries skipping, rides a tricycle, alternates fee when walking up stairs, jumps on two feet, jumps 12”, place beads into a container.
3 ½ years	Stands on 1 foot, hops on 1 foot, when jumping both feet leave the floor.
4 years	Walks 1 foot per step when going down stairs, jumps 20”, can catch a bean bag.
4 ½ years	Hops on 1 foot, overhand throwing, can catch a bean bag hand-to-chest.
5 years	Walks tip toe 5 or more steps, alternating feet skipping.
5 ½ years	Overhand throwing is successful and bean bag catching improving.
6 years	Jumping distance increased, advanced throwing, catch using hands only.

Note. Table adapted from the Gesell Developmental Schedules (Gesell Institute of Human Development, 1979).

Appendix B

Comparison of Language Intervention Target Vocabulary, Mode, Strategies, and Parent Coaching.

Component	AC-I	AC-O	SC
Target vocabulary	Individualized target vocabulary of visual-graphic symbols plus spoken words with use of all target vocabulary during each session. I/P had a card with all target vocabulary listed.	Individualized target vocabulary of visual-graphic symbols plus spoken words with use of all target vocabulary during each session. I/P had a card with all target vocabulary listed.	Individualized target vocabulary of spoken words with use of all target vocabulary during each session. I/P had a card with all target vocabulary listed.
Mode	I/P uses SGD to provide communication input to child.	Child uses SGD to communicate.	I/P and child use speech to communicate.
Strategies	I/P provides vocabulary models to child using the device; symbols are positioned in the environment to mark referents; I/P reinforces the child's productive communications.	I/P provides verbal and/or hand-over-hand prompts so that the child produces communication using the SGD.	I/P provides verbal prompts so that the child produces spoken words.
Parent coaching	I provides coaching for P.	I provides coaching for P.	I provides coaching for P.
Sample interaction	Adult (A) and child (C: Emily) are having a snack. A: Mmm. A: Now what do you want? A: COOKIE or CRACKER. C: vocalizes unintelligible	Adult (A) and child (C: Johnny) are playing with blocks. A: Look Johnny. A: Here are the blocks. A: Tell momma build.	Adult (A) and child (C: Lem) are playing. A: Let's play with the truck. A: Look (A points to mouth).

and holds out hand. A: Cookie or Cracker? C: CRACKER. A: Good. You want a cracker. A: Ok. (A gives a cracker to Emily.) A: That tastes good.	C: PLAY. A: Yep, we’re playin’. A: Tell momma build (A taps SGD). A: Tell me build. C: BUILD (A provides hand-over-hand assistance). A: Good. You want a cracker. A: Alright.	A: Look. A: /t/ /t/ C: XX (vocalizes unintelligibly). A: Truck. C: XX. A: Right? A: Look at my face.

Note. Words in caps indicate speech-generating device (SGD) use. I= interventionist; P= parent; XX=unintelligible vocalization.

[a]Table from Romski et al. (2010)