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The Effects of the Use of a Humanoid Robot on Social Engagement in Two Children with Autism

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ABSTRACT

The Effects of the Use of a Robot during Intervention on

Joint Attention in Children with Autism

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This study examines the effects of intervention using a robot on the social interactions of two children with Autism Spectrum Disorder (ASD). Robots have been shown to facilitate human-robot interaction in children with Autism Spectrum Disorder, yet research has not fully investigated the use of robots to enhance interactions between children with ASD and human conversational partners. The purpose of this study was to investigate the ability of a low-dose intervention procedure using a robot to increase social engagement between each child and his communication partner. Although variable, results were promising and suggested that additional investigation is warranted.

Keywords: autism, robotics, joint attention

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Introduction

Joint attention – the behavior of establishing communicative "partners' shared focus on the same object, entity, or event" (Seibert, Hogan, & Mundy, 1982, p. 248) – is critical to human development, specifically in the areas of communication and social interaction (Seibert et al., 1982). Kasari, Sigman, and Mundy (1990) defined joint attention as "three-way exchanges that involve another, self, and object and may be expressed in the form of referential looks between people and objects, pointing and showing gestures" (p. 88). According to Bruinsma, Koegel and Koegel (2004), a child is participating in joint attention when they have progressed from maintained interest on an object to maintained interest on an object with a communicative partner. In other words, joint attention refers to complex behaviors used with the intent to communicate, verbally or nonverbally, with another person about a third entity.

Types of joint attention include *responding to joint attention* (RJA), *initiating joint attention* (IJA), and *initiating behavior regulation/request* (IBR). RJA involves the ability of a child to follow their communicative partner's eye gaze, head turn, and gestures toward an object or event. RJA is the most basic form of joint attention and is critical to the development of later forms of joint attention, such as IJA. Acts of IJA include the child's use of eye contact and gestures, with the goal of initiating joint attention with a communicative partner. The development of IJA is critical to the social development of the child, and is the foundation for language acquisition (Mundy & Sigman, 2006; Vaughan Van Hecke et al., 2007; Westby, 2010). Both RJA and IJA are used for social communication, with the goal and reinforcement of RJA and IJA being the sharing of a positive social experience with a communicative partner (Mundy & Sigman, 2006; Westby, 2010). Finally, IBR refers to a child's ability to initiate joint attention with the intent to request. IBR is a protoimperative act where the child establishes joint attention using eye gaze and gestures to request an action from a communicative partner (Mundy & Sigman, 2006; Vaughan Van Hecke et al., 2007). For example, a child may reach toward a cup on the counter while looking at their mother. The mother, in turn, hands the cup to the child and the request is fulfilled.

Research shows that the ability to participate in joint attention is critical to social development. Seibert et al. (1982) described three primary areas of social development: social interaction, emotional regulation, and joint attention. They defined social interaction as "behaviors that gain and maintain the attention and interaction of a partner" (p. 248), which is similar to IJA. They defined emotional regulation as "one partner seeks to have a need or want fulfilled or demands a compliant action from the other" (p. 248), which is similar to IBR. Finally, they described joint attention as a behavior to "establish partner's shared focus on the same object, entity, or event" (p. 248), which is similar to RJA and IJA. All three types of joint attention are foundational for social development; if a child does not regularly participate in one or more types of joint attention, he or she may have deficits in one or more areas of social development. Indeed, Mundy et al. (2006) states, "the more frequently infants engage in joint attention, the more comparative social information they have for building richer representations of self and other" (p. 300).

Research shows that children with Autism Spectrum Disorders (ASD) participate in significantly fewer acts of joint attention than their typically developing peers, which may help explain their communication and social delays. Kasari, Sigman, Mundy, and Yirmiya (1990) found that "Disturbances in the development of joint attention behaviors and the ability to share affect with others are two important components of the social deficits of young autistic children" (p. 87). They also stated that young children with autism tend to lack behaviors of joint attention. Mundy, Sigman, Ungerer, and Sherman (1986) compared the behaviors of typical children and children with ASD. Results showed that children with ASD differed most from their typically developing peers in the category of joint attention. The children with ASD used eye contact significantly less often than the typically developing children as a means to share a positive experience with a communication partner concerning a third object.

Two longitudinal studies have shown a significant association between early joint attention skills and the development of social cognition in children in both typically developing children and children with ASD. Vaughan Van Hecke et al. (2007) observed that typically developing 12-month-old infants who frequently engaged with an unfamiliar adult by using eye contact and gestures, and who consistently followed the eye gaze of an unfamiliar adult to an object had higher parent report of appropriate social interactions at the age of 30 months, suggesting that joint attention at a young age does influence social interactions later in life. Similarly, Sigman, et al. (1999) observed that better IJA in preschool children with ASD directly related to the tendency of those children to initiate social interactions.

According to Kasari et al. (1990), joint attention begins in infancy, when an infant and their caregiver engaged in affective interactions. Joint attention behaviors differ from other types of nonverbal communication, such as requesting, by the presence of affect. Kasari et al. (1990) demonstrated that children with ASD displayed significantly less positive affect during interactions of joint attention when compared to typically developing children. This lack of ability to display affect may contribute to the lack of joint attention behaviors seen in children with ASD.

In recent years, research has shown that the use of robots in therapy with children with ASD may increase joint attention behaviors. Results reported by Kozima, Nakagawa, and

Yasuda (2005) suggested that a robot helped facilitate an affective dyadic interaction between a child with ASD and a robot. Robins, Dautenhahn, Boekhorst, and Billard (2005) showed that the use of robots in therapy with children with ASD increased joint attention behaviors, such as eye contact and imitation. It was also noted that the children interacted with the adults in the room while playing with the robot, although adult-child interaction was not part of the study. Still, the results of the study suggest that robots may be used as mediators for joint attention between a child with ASD and an adult. It has yet to be determined, however, if the use of a robot as a mediator between a clinician and a child with ASD will increase joint attention interactions between the child with ASD and a human communicative partner.

The purpose of the present study was to investigate the effects of introducing a robot in treatment sessions with two children with ASD. Specifically the study was designed to determine if exposure to the robot would result in increased social engagement and joint attention between the children and adult conversational partners (parent or clinician) when the robot was not present. Thus, this study investigated whether or not instances of social engagement, including RJA, IJA, and IBR, increased in both frequency and duration in children with ASD following robot intervention.

Literature Review

Over the past two decades much research has examined joint attention, specifically joint attention trends seen in children with autism. This review will examine (a) the characteristics and diagnosis of Autism Spectrum Disorders (ASD), (b) historical literature regarding joint attention, (c) the connection between joint attention, language development, and children with autism, (d) current intervention procedures used in therapy for children with ASD, and (e) relevant research regarding the use of a humanoid robot in therapy for children with ASD.

Autism

In Rapin's (1991) review of the literature, the term Autism Spectrum Disorders (ASD) is defined as "a behavioral syndrome, present from early life and defined by deficient social interaction, language and communication, and play…" (p. 751). The American Psychological Association (2000) defined three key features of Autism Spectrum Disorder: (a) deficit of social interactions and social communication, (b) deficit of receptive and expressive communication, and (c) excessive use of non functional, repetitive behaviors and movements. Although all three features characterize children with ASD, this study primarily addresses the deficient social interactions seen in children with ASD.

The criteria for diagnosing ASD are entirely behavioral. The most common and most widely accepted guidelines used to identify ASD in the United States are found in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV; American Psychiatric Association, 2000). According to the text Autism Spectrum Disorders: Issues in Assessment and Intervention (as cited in American Psychiatric Association, 2000) a child must demonstrate the following characteristics in order to be identified with ASD:

> A. A total of six (or more) items from (1), (2), and (3), with at least two from (1) and one from each of (2) and (3): (1) qualitative impairment in social interaction, as manifested by at least two of the following: (a) marked impairment in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction, (b) failure to develop peer relationships appropriate to developmental level, (c) lack of spontaneous seeking to share enjoyment, interests, or achievements with other people (e.g., by a lack of showing, bringing, or pointing out objects of interest), (d) lack of social or emotional reciprocity, (2) qualitative impairment

in communication, as manifested by at least one of the following: (a) delay in, or total lack of, the development of spoken language (not accompanied by an attempt to compensate through alternative modes of communication such as gesture or mime), (b) in individuals with adequate speech, marked impairment in the ability to initiate or sustain a conversation with others, (c) stereotyped and repetitive use of language or idiosyncratic language, (d) lack of varied, spontaneous make-believe play of social imitative play appropriate to developmental level, (3) restricted repetitive and stereotyped patterns of behavior, interests, and activities, as manifested by at least one of the following: (a) encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal in either intensity or focus, (b) apparently inflexible adherence to specific, nonfunctional routines or rituals, (c) stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting, or complex whole-body movements), (d) persistent preoccupation with parts of objects.

B. Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years: (a) social interaction, (b) language as used in social communication.

C. The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder (p. 11).

Characteristics of ASD. The three key features of ASD are social deficits, speech and language deficits, and excessive and repetitive behaviors (Rapin, 1991). Each key feature is discussed in detail below.

Social deficits. According to Rapin (1991), the key feature of ASD is the significant deficit of social interaction; children with ASD do not interact appropriately with others socially.

For example, infants with ASD often resist cuddling. Likewise, preschoolers with ASD may bump into others without recognition or acknowledgment of their presence, fail to turn around when their name is called, and/or avoid eye contact with individuals trying to engage them in conversation or play. Children with ASD often struggle with intersubjectivity. They are often completely unaware of others' thoughts and feelings or the negative impact their behavior may have on others. Additionally, individuals with ASD often have difficulty interpreting the facial expressions and emotions of others. Children with ASD have difficulty engaging, interacting, or making friends with their peers, which may lead to isolation.

Children with ASD also have severe deficits in the ability to participate in imaginative play, which further affects their ability to interact socially with their peers. Unlike typically developing children, children with ASD frequently must be taught explicitly how to participate in symbolic play. Otherwise, children with ASD tend to manipulate toys by lining them up, twirling, or banging them instead of using toys during imaginative play (Rapin, 1991).

Speech and language deficits. The American Psychiatric Association (2000) states that all preschool aged children diagnosed with ASD have some type of developmental language disorder. According to Rapin's (1991) literature review, characteristics of the language disorders in children with ASD vary from child to child and include impaired receptive language, impaired expressive language, mutism, speech unintelligibility, jargon, echolalia, excessive speech, and repetitive speech. Pragmatic skills are also often deficient in children with ASD. They have difficulties participating in conversations, initiating topics, maintaining topics, taking turns, making eye contact, or interpreting prosody or facial expressions (Rapin, 1991).

Excessive and repetitive behavior. According to Campolo et al. (2008, September), children with ASD often display repetitive, nonfunctional motor movements, such as hand flapping, twirling, humming, rocking, and head banging. They often have trouble with eye gaze, gait and often resist change to their environment, insisting on and maintaining an unusual tolerance for monotony and routine.

Other characteristics. Rapin (1991) states that some children with ASD are described as having flat emotional affect because they often do not react to reward or punishment. Other children with ASD are highly moody, irritable, and excessively aggressive, and many have frequent temper tantrums. Impairments of attention are also often common among children with ASD. Some children with ASD are hyperactive and highly distractible, wandering from activity to activity without ever engaging in an activity. However, other children with ASD have abnormally long attention spans for certain objects that interest them; however, these interests are rarely interactive.

Prevalence and etiology of ASD. According to the Centers for Disease Control and Prevention (2007), approximately 1 in 150 children in the United States is diagnosed with ASD. Autism is a behavioral syndrome with no specific etiology, and the etiology is unknown in most cases. In a small number of individuals, the cause of ASD can be traced to specific syndromes, such as fragile X syndrome, congenital rubella, and tuberous sclerosis; however, none of these syndromes is consistently related to ASD (Rapin, 1991).

The nature of pervasive developmental disorder not otherwise specified. Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) is one of three main categories that make up Autism Spectrum Disorders. It is used to characterize children who present with atypical autism, and therefore do not meet the strict criteria for a diagnosis of autism, as provided in the DSM-IV (American Psychiatric Association, 2000). In the text *Autism Spectrum Disorders: Issues in Assessment and Intervention* (as cited inAmerican Psychiatric Association, 2000), in order for a child to be diagnosed with PDD-NOS, they must demonstrate the following: “pervasive impairment in social interaction; pervasive impairment in communication skills OR presence of stereotyped patterns of behavior, interests, or activities, which does not meet the criteria for a specific Pervasive Developmental Disorder; and presence of impairments that do not meet the criteria for Autistic Disorder because of late age at onset, atypical symptoms, or subthreshold symptoms” (p. 10).

Because a diagnosis of ASD is entirely behavioral, it can sometimes be difficult for practitioners to determine whether or not a young child’s developmental difficulties are due to ASD or some other difficulty. Young children who present with some, but not all, of the impairments characteristic of autism or who present with all of the characteristics of autism, but to a lesser degree, are often characterized as presenting with PDD-NOS. Thus, early diagnoses of PDD-NOS are not as stable as diagnoses of ASD; however, a majority of toddlers diagnosed with PDD-NOS qualify for a diagnosis of ASD by the age of nine, and it is not uncommon for a practitioner to make an early diagnosis of PDD-NOS, then later change the diagnosis to ASD after additional impairments have been identified (Prelock, 2006). Speech-language pathologists, however, typically provide the same type of treatment to children diagnosed with PDD-NOS as they do for children diagnosed with ASD because both disorders fall on the autism spectrum and are thus considered as ASD (Chawarska, Klin, & Volkmar, 2008).

Joint Attention

Understanding joint attention and how it relates to social engagement and language development in typically developing children and children with ASD is critical because children with ASD tend to engage in behaviors of joint attention far less often than their typically developing peers. Therefore, the following review will discuss recent and relevant research on joint attention, the types of joint attention, development of joint attention in typically developing children, the relation of joint attention to social engagement and language development, and joint attention in children with ASD.

Seibert, Hogan, and Mundy (1982), defined joint attention as a communicative behavior where the primary goal is to "establish both partners' shared focus on the same object, entity or event…to look at something together" (p. 248). Seibert et al. (1982) further separates joint attention from social interaction by stating that social interactions are "behaviors that gain and maintain the attention and interaction of the partner, primarily for playful purposes (i.e., the pleasure of the interaction) or for contact or proximity" (p. 248).

Mundy and Sigman (2006) defined joint attention as the ability of a child and their communicative partner to be aware of their common perceptions of an object. According to Bruinsma, Koegel and Koegel (2004), a child is participating in joint attention when they have progressed from maintained interest on an object to maintained interest on an object with a communicational partner. Vaughan Van Hecke et al. (2007) divided joint attention into three dimensions: "(a) the tendency to express agreeableness, interest in others, and positive emotions with peers, as well as adults, (b) the ability to integrate the behavior of self with others in the dynamic flow of social interaction, and (c) the ability to regulate attention and emotional reactivity, including the ability to self-monitor and correct errors, in positive goal-related activity" (p. 53). Finally, Westby (2010) defined joint attention as "the integration of information about self-experience of an object or event with information about how others experience the same object or event" (p. 137). Thus, joint attention refers to complex behaviors used with the intent to communicate, verbally or nonverbally, with another person about a third entity.

Types of joint attention. There are several types of joint attention. One form is referred to as *responding to joint attention* (RJA). RJA involves the ability of a child to follow their communicative partner's eye gaze, head turn, and gestures (Mundy & Sigman, 2006; Vaughan Van Hecke et al., 2007; Westby, 2010). Another form of joint attention is called *initiating joint attention* (IJA). Acts of IJA include the child's use of eye contact and gestures, with the goal of initiating coordinated attention with a communicative partner. IJA is a protodeclarative act, meaning the child has the ability to attract another's attention to an object of interest, show positive emotional affect concerning an object of interest, and use an object to obtain another's attention. The development of IJA is critical to the social development of the child, and is the foundation for language acquisition (Mundy & Sigman, 2006; Vaughan Van Hecke et al., 2007; Westby, 2010). Both RJA and IJA are used for social communication, with the goal and reinforcement of RJA and IJA being the sharing of a positive social experience with a communicative partner (Mundy & Sigman, 2006; Westby, 2010).

The final form of joint attention is referred to as *initiating behavior regulation/requests* (IBR). IBR has less of a social purpose and more of an instrumental purpose in communication. As such, IBR is a protoimperative act, meaning the child has the ability to use eye contact and gestures to elicit aid or request an object or event (Mundy & Sigman, 2006; Vaughan Van Hecke et al., 2007).

Joint attention and theory of mind. Theory of mind is also referred to as intersubjectivity, and is defined as the "ability to predict behaviors of others and participate in effective social conversation" (Westby, 2010, p. 137). Westby (2010) refers to two types of intersubjectivity: *primary intersubjectivity* and *secondary intersubjectivity*. *Primary intersubjectivity* develops by six months of age and is characterized by the ability to "use and respond to eye contact, facial affect, vocal behavior, and body posture in interaction with others" (Westby, 2010, p. 137). *Primary intersubjectivity* allows the infant to develop the awareness that they participate in distinct affective experiences with others. *Primary intersubjectivity* serves a social function, and infants are displaying *primary intersubjectivity* when they are participating in acts of RJA (Westby, 2010). *Secondary intersubjectivity* develops between 6 and 18 months of age and is characterized by the child's "conscious awareness of both self and others as sharing an experience" (Westby, 2010, p. 137). It supports and increases the infant's ability to intentionally engage in social communication. *Secondary intersubjectivity* positively reinforces the child, which creates ongoing motivation for the child to participate in social interactions. IJA is a type of *secondary intersubjectivity* (Westby, 2010).

Intersubjectivity is critical to social development. Indeed, Westby (2010) stated that "to participate effectively in social situations, children must be able to infer and interpret their partners' emotional reactions" (p. 155). Mundy and Sigman (2006) stated that, "Intentional participation in communication implicitly suggests that infants are aware that social partners have the mental capacity to receive and interpret communicative signals." In other words, in order to effectively communicate with others, children must develop the skill of intersubjectivity. A child cannot develop intersubjectivity, however, without first developing joint attention skills. Westby (2010) states that without the development of joint attention skills, specifically RJA and IJA, children cannot develop the ability to share emotionally with others. Without emotional sharing, children fail to develop episodic memory, which is the ability to connect emotional experiences of an event to the what, when, and how of the event. Episodic memory allows individuals to use experiences in their past to make predictions about similar future experiences. Intersubjectivity and episodic memory are interdependent; without episodic memory, higher levels of intersubjectivity, which are essential for social understanding and the development of interpersonal relationships, fail to develop.

Development of joint attention in typical children. Bates (1979) produced ground breaking work on the subject of the emergence of intentional communication in infants, and provided three characteristics of intentional communication. The first characteristic involves joint attention behaviors, such as eye gaze between an object and the infant's communication partner. The second characteristic is the child's perseverance in displaying acts of joint attention, such as vocalization, gesturing, and eye gaze, until the communicative goal is met. The final characteristic is the child's vocalizations closely resembling typical speech patterns and sounds.

Seibert et al. (1982) developed a system of five levels, ranging from Level 0 to Level 4, used to describe the development of joint attention and social interaction in children. These levels are described as follows:

- *Level 0: Reflexive or Responsive* was observed in infants younger than two months. During this stage, an infant was described as being socially interactive when the infant was soothed by a communicative partner. Infants were described as participating in joint attention when they attended to an object shown to them by a communicative partner. Infants engaging in Level 0 behaviors were not acting with conscious intent to interact with a partner; rather, intentional communication eventually develops from these unconscious acts.
- *Level 1: Simple, Voluntary Interactions* were observed in infants between the ages of two and seven months. At this level, infants demonstrated increasingly greater voluntary control over their behaviors. Infants at this level are able to voluntarily direct their gaze to examine objects or individuals and voluntarily reach out for desired objects in their

environment. Social interaction behaviors include (a) visual recognition of familiar individuals, often accompanied by a smile; (b) participation in and enjoyment of reciprocal vocal and gestural play; (c) the use of simple vocalizations and gestures during social games to demonstrate a desire to continue the interaction; (d) initiating interactions by reaching towards objects or individuals; and (e) verbal and emotional protests upon the withdrawal of social interactions. Joint attention behaviors include the spontaneous alternating eye contact between the communicative partner and the object of interest. Though infants at this level demonstrate more voluntary control of social behaviors, these children still do not act with full conscious intent.

- *Level 2: Complex Differentiated Interactions* are first seen in children between the ages of 8 and 12 months. It is during this stage that infants first use these behaviors with conscious intent to communicate with another individual. Social interaction behaviors include (a) differentiating between individuals by displaying caution toward unfamiliar individuals, (b) responding to his or her name, and (c) initiating requests for attention or an interaction toward partners at a distance through use of eye contact and vocalizations and/or gestures. Joint attention behaviors include (a) pointing, (b) alternating glances between an object and an individual, and (c) participating in joint attention sequences, such as reading a book.
- *Level 3: Immediate Modification of Interactions to Feedback* is seen in infants between the ages of 13-21 months. At this level, the child begins to modify his or her own actions and is able to simultaneously focus on an object and an individual. Social interaction behaviors include (a) spontaneously initiating interactions by using learned gestures and vocalizations of familiar games, (b) use objects in turn-taking sequences, and (c)

awareness of social convention and the use of teasing during play. Joint attention behaviors include (a) reliably looking where a communicative partner is pointing or looking, even at a distance; (b) looking toward an object when the object's name is used; (c) spontaneously initiating joint attention by showing their communicative partner interesting objects; and (d) using one-word utterances to direct their communicative partner's attention.

- *Level 4: Anticipatory Regulation of Interactions* are seen in children between the ages of 18-22 months. This level is characterized by the child's ability to experience symbolic and representational thought, which allows the child to anticipate some of the consequences associated with his or her actions. Social interaction behaviors include (a) incorporating pretend play into interactions, and (b) using and understanding simple word combinations to sustain interactions. Joint attention behaviors include (a) responding to a communicative partner's attempt to direct their attention to an object out of view, and (b) participate in a more detailed information exchange concerning objects of mutual interest.

Mundy and Sigman (2006) confirmed the work of Seibert et al. (1982). Mundy and Sigman noted that infants as young as three months can participate in joint attention behaviors and IJA and RJA are fully developed by 18 months. They noted that in the first year of life joint attention behaviors are largely visual and exist in the here and now. However, as a child develops, joint attention behaviors become more complex and he or she is able to attend to more abstract concepts, such as conversations, with adults (Mundy & Sigman, 2006).

Joint attention and social development. Seibert et al. (1982) provided three primary areas of social development: social interaction, emotional regulation, and joint attention. They defined social interaction as "behaviors that gain and maintain the attention and interaction of a partner" (p. 248). Emotional regulation was defined as "one partner seeks to have a need or want fulfilled or demands a compliant action from the other" (p. 248). Finally, joint attention was defined as "establish partner's shared focus on the same object, entity, or event" (p. 248).

Mundy and Sigman (2006) defined social competence as a pre-social behavior that involves several processes, including, "(l) the ability to regulate attention and emotional reactivity in the dynamic flow of social interaction; (2) the ability to self-monitor, correct errors, and integrate the behavior of self with others in positive goal-related activity; and (3) the tendency to express agreeableness, interest in others, and positive emotions with peers and adults" (p. 294). Mundy and Sigman further stated that joint attention is critical to social development because it helps the child integrate information about their own experiences with an object or event and compare them to others' experiences with an object or event.

> Therefore, the more frequently infants engage in joint attention, the more comparative social information they have for building richer representations of self and other. Hence, joint attention may be regarded as an early developing *self-organizing facility* that serves to elicit and/or organize social information input in a manner that optimizes early social learning and social development. (p. 300)

If joint attention assists children in organizing social input, then more consistent and frequent use of joint attention skills may lead to more social learning opportunities for infants and children. In other words, differences in the frequency and appropriate use of joint attention skills may affect a child's overall social development (Mundy & Sigman, 2006).

In her article, Westby (2010) stated that social competence underlies social communication and develops from early emotional sharing between infants and caregivers. She further defined three integrated elements of social development: *secure attachment, instrumental social actions*, and *experience sharing*. *Secure attachment* refers to the affective connection between an infant and their caregiver. *Instrumental social actions* are used to accomplish a specific goal during a social interaction, such as pointing to an out-of-reach toy. *Instrumental social actions* are acts of IBR and are externally reinforced. *Experience sharing* refers to, "the desire and skills to be a good reciprocal playmate, to value others' point of view, to develop friendships, and to conduct emotion-based interactions, without concern for external rewards. *Experience sharing* requires the individual to constantly reference the emotional states and actions of their communicative partners and base their own actions on these evaluations" (Westby, 2010, p. 136).

The role of social cognition in joint attention. Research shows that joint attention is critical to the development and function of social cognition in children in several ways. First, the amount of IJA behaviors seen in children directly relates to the degree to which the child enjoys sharing experiences with others. The goal of joint attention is to share positive social experiences with others. As a child shares these positive social experiences, they will ideally gain a desire to continue sharing positive social experiences with others, thus naturally reinforcing the behavior. Second, Vaughan Van Hecke et al. (2007) stated that "infants' intentional use of eye contact and gestures in joint attention is thought to mark the early development social cognition, or the awareness that others have powers of perception and intention that may be affected by social signals" (p. 55). Finally, the development of joint attention aids in the development of attention, inhibition, and self-monitoring, which are all critical elements involved in the development of social competence.

Two longitudinal studies have shown a significant association between early joint attention skills and the development of social cognition in children in both typically developing children and children with ASD. Vaughan Van Hecke et al. (2007) observed that typically developing 12-month-old infants who used eye contact and gestures to engage with an unfamiliar adult and who consistently followed the eye gaze of an unfamiliar adult to an object had higher parent report of appropriate social interactions at the age of 30 months, suggesting that joint attention at a young age does influence social interactions later in life. Similarly, Sigman, et al. (1999) observed that better IJA in preschool children with ASD directly related to the tendency of those children to initiate social interactions.

The role of affective exchange of joint attention. As Westby (2010) stated in her article, the ability to demonstrate affect and understand affect in others is a key component of joint attention and social development. Westby (2010) states “Infants are born with endogenous processes that enable them to perceive people as being similar to themselves. This awareness is not based on facial features or movement, but rather on affective awareness” (p. 138). Typically developing infants develop the ability to recognize whether their emotions and the emotions of others are similar. By the end of their first year, infants are able to engage in social referencing, which is the ability to perceive the connection between their communicative partner’s affect and the corresponding stimulus. Infants use social referencing to make judgments concerning how they should respond to a particular situation. Thus, the ability to understand and display affect in social situations in crucial for children to learn in order for them to respond to social situations appropriately (Westby, 2010).

Joint attention and language development. In typical developing children, the development of joint attention is closely related to the development of intentional communication. Joint attention, specifically IJA, is critical to language acquisition in children (Bruinsma et al., 2004). Intentional communication results when an infant begins to understand that another individual can aid in achieving a goal, and that the infant can use nonverbal communication to influence that individual's actions (Bates, 1979). As a child matures, this nonverbal communication becomes intentional as a result of communication partners consistently attributing meaning to an infant's actions (Bruinsma et al., 2004).

There is substantial evidence showing a relationship between joint attention and language acquisition in typical children. A study done by Markus, Mundy, Morales, Delgado, and Yale (2000) showed that the amount of time children spent in joint attention interactions is positively related to the size of the child's vocabulary. Likewise, studies done by Mundy, Sigman, and Kasari (1990) and Mundy, Karsari, Sigman, and Ruskin (1995) showed that the rate of IBR, IJA, and RJA were positively related to the size of the child's expressive and receptive vocabulary. These studies give evidence that suggest a strong relationship between the amount of time spent in a joint attention interaction and language development.

Joint attention in children with ASD. A key feature of joint attention is the ability to divide one's attention between a communicative partner and an object. This most often involves eye contact, which may be difficult for children with ASD. In a study that compared the behaviors of typical children and children with ASD, Mundy, Sigman, Ungerer, and Sherman (1986) discovered that children with ASD differed in the category of joint attention. The children with ASD used eye contact significantly less than the typically developing children as a means to share a positive experience with a communication partner concerning a third object. Osterling and Dawson (1994) compared typically developing children and children with ASD on their first birthday. Results showed that frequency and duration of eye contact was the best predictor of a future diagnosis of ASD. Results of a study done by Wimpory, Hobson, Williams, and Nash (2000) showed that parents of children with ASD noticed less frequent use of joint attention behaviors, including eye contact, giving, showing, and pointing than did parents of typically developing peers. Parents of children with ASD also noted that their children made fewer preverbal vocalizations in attempt to communicate as infants.

Difficulty with joint attention may explain some of the difficulties children with ASD experience in social communication. Wetherby and Prutting (1984) examined how typically developing children used language compared to children with ASD. They found that the children with ASD primarily participated in protoimperative acts of communication. That is, they used pre-verbal behaviors to request objects or actions. In contrast, typically developing children participated in both protoimperative and protodeclarative acts of communication. These children used pre-verbal behaviors not only to request objects or actions, but also draw their conversational partner's attention to objects of interest.

Speech and Language Treatment for Children with ASD

Over the past several years, a great deal of research has examined interventions for children with ASD. Studies examining interventions for children with ASD and specific treatment options for joint attention and social engagement are discussed below.

Levy, Kim, and Olive (2006) comprised a review of the available literature on interventions for children with ASD. They reported that interventions that targeted "social skills, language acquisition, nonverbal communication, and behavior management greatly improved the lives of children with autism" (p. 55). Levy (2006) reviewed 24 studies investigating various communication interventions for children with ASD. They described six categories of intervention: (a) *parent involvement*, (b) *intensive behavioral intervention*, (c) *multi-component* *early intervention*, (d) *language/speech treatment*, (e) *setting*, and (f) *other*. Overall, results of the review showed that interventions which included parent involvement, behavioral modification, several target variables, and long duration of intervention were the most effective interventions for children with ASD. Indeed, all reviewed studies that included parent involvement and/or long treatment duration yielded positive results. Specific results of the review are explained below.

- *Parent involvement:* Levy et al. (2006) reviewed six studies in which parents trained an educated in various target areas, and were then implemented as the primary intervention deliverer. Speech, language, and behavioral management were targeted in three of the six studies, and social interaction/communication was targeted in four of the six studies. Results included a significant increase in speech skills, language development, social interaction, cognitive functioning, and behavior management, and a significant decrease of the presence of characteristics of ASD. Parent intervention may be successful for the following reasons: (a) parents can increase the amount of intervention without increasing cost, (b) parents can intervene throughout the child's life, and (c) educated parents report increased feelings of competence and support and decreased feelings of depression and stress.
- *Intensive behavioral intervention:* Levy et al. (2006) reviewed four studies where children with ASD received intensive behavioral intervention for several months. Results showed significant increases in intelligence scores, social development, academic development, language development, and adaptive behaviors, and a significant decrease in the severity of autistic behaviors. It was also noted that significant improvement of problem behaviors was more likely when the intervention occurred before the child was

60 months of age. Results also showed a significant increase in the probability of the child with ASD to complete first grade in a general education classroom.

- *Multi-component early intervention:* Levy et al. (2006) reviewed two studies where children with ASD received multi-component early intervention for several months. Language development, social development, cognitive development, and behavior management were targeted in these studies. Results showed significant increases in play behaviors, cognitive development, language development, and social development, and a significant decrease of autistic behaviors. Results also showed a significant increase in the probability of a child with ASD to complete first grade in a general education classroom.
- *Speech and language treatment:* Levy et al. (2006) reviewed three studies where language acquisition and development was targeted. Two of the three studies showed significant increases in auditory comprehension, nonverbal imitation, vocal imitation, and vocabulary.
- *Setting:* Levy et al. (2006) reviewed four studies investigating the effect of the presence of typically developing children on children with ASD. Two of the four studies showed significant increases in social behavior in the children with ASD, and significant decreases of autistic behaviors. However, though both studies showed an increase of social interaction between the typically developing peers and the children with ASD, these interactions were largely initiated by the typically developing children.

McConnell (2002) reviewed 55 studies of interventions for social interactions for children with ASD. Each study was placed in one of the following five categories: (a) *ecological* *variations*, (b) *collateral skills intervention*, (c) *child-specific interventions*, (d) *peer behavior*, and (e) *comprehensive interventions*. Specific results of the review are explained below.

- McConnell (2002) reviewed 11 studies investigating the effect of the presence of typically developing children on children with ASD. They found that the simple presence of typically developing children without additional intervention did not increase social behaviors in children with ASD.
- *Collateral Skills Intervention:* Collateral skills intervention refers to interventions that target increases in social interaction through the development of various skills, such as sociodramatic play and appropriate academic response, and increased understanding of and opportunities to participate in social interactions (McConnell, 2002). McConnell (2002) reviewed nine studies in this category. All nine studies showed an increase of social participation and communication in children with ASD.
- *Child-specific Intervention:* Child-specific interventions are designed to increase social behaviors in children with ASD. McConnell (2002) analyzed 15 child-specific intervention studies. Results showed that child-specific interventions directly (through intervention) and indirectly (through generalization) increase social behaviors in children with ASD. However, McConnell (2002) noted that these studies were less successful long-term, possibly due to the focus on initiating social interactions and weak reinforcement during intervention.
- *Peer-mediated Intervention:* Peer-mediated interventions provide social skills training to typically developing children that frequently associate with children with ASD, in order to encourage social skills and interactions in children with ASD. McConnell (2002)

reviewed 30 peer-mediated intervention studies. Results showed that peer-mediated interventions are largely successful at increasing social interaction in children with ASD.

- *Comprehensive Interventions:* Comprehensive interventions are interventions that include two are more of the interventions mentioned above. McConnell (2002) analyzed seven comprehension intervention studies. Results showed that studies that combine interventions directed at both children with ASD and their typically developing peers increase social behaviors in children with ASD. These studies also found that comprehensive intervention strategies promote generalization to other settings.

The Use of Humanoid Robots in Interventions for Children with ASD

Recently researchers have begun to examine the use of technology, specifically robot technology, in therapy for children with ASD. In the past few years, several studies have examined the use of robots in therapy for children with ASD. Most of these studies examined whether or not children with ASD engaged in social interactions with the robot and whether or not the use of a humanoid robot in therapy increased behaviors of joint attention seen in children with ASD. The importance of robot design and current studies examining the use of a humanoid robot in therapy for children with ASD are discussed below.

Robot Design. Ray, Mondada, and Siegwart (2008) surveyed human perceptions of robots and discovered that a vast majority of individuals view robots positively. Most individuals reported, however, that they viewed robots as useful tools for daily activities, but they had not thought of, or desired to use robots as social partners. Ray et al. (2008) asserted that for people to respond to robots in a social manner, it is critical that the robot's design meet human expectations for a conversational partner. That is, the robot must display a social function and anthropomorphic attributes.

According to Duffy (2004), robots can be designed to fit in one of three categories: abstract, human, or iconic. The appearance of an abstract robot is far removed from human appearance, so as not to resemble human characteristics, while a human robot is built to resemble human characteristics as much as possible. Iconic robots are designed with human characteristics, but they are not designed to directly copy those characteristics. Rather, these robots look robotic, yet maintain human features, such as eyes, mouth, arms, etc. Duffy stated that if a robot appears too much like a human, people are more apt to respond negatively to it. On the other hand, if the robot appears too much like a machine, people are more apt to treat it as a machine as opposed to a social partner. Thus, people may respond most socially to an iconic design.

One key feature of an anthropomorphic robot is the robot's face. Edsinger, O'Reilly, and Breazeal (2000) state that the robot's face creates opportunity for humans to perceive a personality in the robot, and thus interact socially with it. Another key feature of an anthropomorphic robot is the robot's name. According to Duffy (2004), humans are much more likely to respond socially to an object that is named because it makes the robot sentient. Finally, to be anthropomorphic, a robot must display movement. According to Premack and Premack (1995), intentional movement is an anthropomorphic behavior, and children can distinguish between unintentional and intentional movement from an early age. Thus, a social robot must display movement that appears intentional in order for an individual to perceive the robot as a social entity.

In addition to being anthropomorphic, a robot and its interface must be functional and accessible to be of any use to the users. Lee, Toscano, Stiehl, and Breazel (2008) provide six features that are necessary for a robot to function socially. First, the operating systems of the robot must be designed so that the operator of the robot can easily direct the attention of the user of the robot. Second, the robot must be designed so that both the operator and the user can share attention easily with each other and the robot. Third, the robot should be designed so that it provides the user with multi-modal sensory information, such as auditory, tactile, and visual stimuli. Fourth, the robot should be easy to control, so that the operator is free to engage in rich interactions with the user without being distracted by the mechanics of the robot. Fifth, the robot's expressions must convey personality and be easily understood by those using the robot. Finally, the robot's interface must be accessible to the operator, in order for the operator to make appropriate adjustments to fit the individual user.

The Use of Robots to Address Joint Attention in Therapy. The most recent and extensive research in the use of robotics in therapy for children with ASD has been the *Autonomous Robotic Platform as a Remedial Tool for Children with Autism* (AURORA) project. The AURORA project is an extensive longitudinal study on the use of iconic humanoid robots with children with ASD, involving many researchers and several different types of robots. The purpose of the Aurora project was to investigate how a robot might be a tool to encourage children with ASD to engage in social behaviors, such as joint attention, that are critical to human social development. Several studies involved in the Aurora project are described below.

Dautenhahn and Werry (2004) introduced children with ASD to robots in play situations and found that the children were highly interested and engaged in playing with the robotic toys. Robins, Dickerson, Stribling, and Dautenhahn (2004) showed that children with ASD used a robot as an object of focus to initiate joint attention with a human communication partner.

Robins, Dautenhahn, Boekhorst, and Billard (2005) conducted a longitudinal study with four children diagnosed with ASD who interacted with a humanoid robot for several months.

The purpose of the study was to encourage the children with ASD to initiate and engage in social interactions through the use of basic imitative and turn-taking games. The frequency of joint attention behaviors, such as eye contact and imitation, that the children with ASD engaged in with the robot were evaluated. They found that as the children interacted with the robot, there was an increase of eye contact and imitation behaviors over the duration of the study. Further, the authors noted an increase of adult-child interactions where the robot was a mediator for human to human interaction, suggesting that robots may be used in therapy to promote human-human joint attention interaction.

Robins and Dautenhahn (2006) investigated triadic interactions between a robot, an adult, and a child with ASD. They discovered that, while playing with the robot, children with ASD spontaneously invited adults present in the room to become involved in a triadic interaction with them and the robot. Once the triadic interaction was established, the children with ASD frequently participated in joint attention with the adults by making eye contact, participating in turn-taking exchanges, and imitating the adult's movements.

Francois, Powel, and Dautenhahn (2009) used non-directive play techniques along with regulation processes to encourage six children with ASD to participate in dyadic or triadic social play with a robot, Aibo, and a communication partner. Because the play was non-directive, the experimenter's role was to listen to, respond to, an answer questions posed by the child. The experimenter also redirected the child's play to (a) prevent or discourage repetitive behaviors, (b) encourage the child to engage in play, (c) regulate the pace of the interaction, (d) scaffold higher levels of play, and (e) encourage affect or reasoning. Results showed that one child exhibited an increased frequency of imitative behaviors, and three children exhibited increased frequency and complexity of social play, including initiating joint attention with the experimenter.

The Communication-Care project is another extensive, longitudinal study on the use of iconic humanoid robots in therapy for children with ASD. Kozima et al. (2005) and Kozima and Nakagawa (2006) published similar studies as part of the Communication-Care project. Results of their studies showed that children with ASD participated in dyadic interactions with their robot, Keepon. While playing with Keepon, children with ASD showed an increased interest and desire to initiate and maintain triadic interactions with Keepon and a communication partner, such as their mother or another child.

Feil-Seifer and Mataric (2008) and Feil-Seifer et al. (2009) showed that children with ASD respond socially to a robot in therapy. Further, results showed that children with ASD are more likely to respond socially to a robot that responded contingently to the child's behavior, as opposed to a robot that engaged in behaviors randomly. When the robot responded contingently, the children exhibited more frequent vocalizations and communication with their parents. These results suggest that the children with ASD preferred a robot that acted as a social partner who would participate in predictable social exchanges, rather than a robot that acted as a toy. In a similar study, Feil-Seifer et al. (2009) found that the children with ASD attempted to initiate conversation with the robot. However, the robot was not programmed to produce vocalizations so it was unable to respond to the children's initiation of a social interaction. Feil-Seifer et al. (2009) also found that several of the children with ASD developed social expectations of the robot, such as expecting the robot to wave back when the child waved, or expecting the robot to play tag when the child ran away. These findings suggest that further research is needed to determine whether or not a robot used in therapy with children with ASD would increase social interactions between the child with ASD and a human communication partner.

Summary

The purpose of this study was to extend the research concerning the use of a humanoid robot on social engagement in children with ASD. Although current research suggests children with ASD are engaged and motivated by humanoid robots and therefore display increased behaviors of joint attention, research has been unable to demonstrate generalization of behaviors of social engagement to human communication partners. Thus, this study examined whether or not two children with ASD displayed generalization through increased social engagement with a human communication partner without the presence of a robot after a period of therapy which included the use of a humanoid robot.

Methods

Two male children identified with ASD were selected to participate in this study based on several considerations as discussed below. Data used for this study were gathered from January 2010 to May 2010. All procedures were approved by the Brigham Young University Institutional Review Board.

Participants

Two male children who were receiving services at the BYU Speech and Language Clinic were included in this study. These children demonstrated moderate to severe deficits in social and communicative function, limited joint attention behaviors, and moderate to severe language delay. Further, these two children had shown little improvement in social communication during the previous year despite their enrollment in special services including speech and language therapy at the BYU Speech and Language Clinic. The participants will henceforth be referred to as Alex and Chris. The participant’s names have been changed to protect their privacy.

Alex. Alex was a three-year-old male with a diagnosis of PDD-NOS. In January, 2009, at the age of 24 months, Alex was seen by a pediatric neurologist who diagnosed him with hypotonia. The pediatric neurologist had further concerns about Alex's delayed development; therefore, Alex was referred to a child psychologist for further testing. The child psychologist then identified Alex with PDD-NOS using the Autism Diagnostic Observation Schedule. Other noted deficits included borderline IQ, language delay, sensory problems, and gross motor delays.

Birth and medical history and motor milestones. The following information was gathered from a case history form filled out by Alex's mother in January, 2009, when he was 30 months old.

Alex lived at home with his mother, father, and six siblings, five older and one younger. His prenatal history was unremarkable, with gestation lasting 38 weeks and no reported complications with delivery. Alex was a healthy infant and toddler with no known medical conditions or allergies; however, Alex presented with hypotonia, especially in the lower body, causing difficulty walking, running, and passing bowel movements. He exhibited hypersensitivity to food and a hyperactive gag reflex. Alex's mother had been concerned about him since his birth due to his inattention to faces, failure to reciprocate a social smile, and delayed attainment of developmental milestones. Alex sat up at six months, crawled at 14 months, and walked at 27 months. Results of a hearing evaluation at age 3:6 were within normal limits.

Speech and language development. Alex's first words were *dad* and *tub* at the age of 20 months; however, his mother reported that Alex lost those vocabulary words by the age of 24 months. At 30 months, Alex had no verbal language. He communicated his wishes by taking his mother's hand and walking with her to what he wanted, such as to the refrigerator or the pantry.

His receptive language skills were limited to the understanding of a few commands, such as *let's go*. Alex did not respond to other commands such as *stop*, *wait*, *eat*, and *sleep*. His mother was not aware of any family history of speech, language, or hearing problems; however, two of his older brothers did not talk until they were 2-3 years of age, when they then "exploded with language." His mother noted that Alex had a paternal cousin with Asperger Syndrome, a paternal aunt with spina bifida, and a paternal grandfather with a history of motor delays.

Social development. Alex's mother stated that he had a limited attention span for both self-directed and adult-directed activities. He did not have any regular playmates beyond his siblings; however, he enjoyed playing with his older siblings. Play with his older siblings consisted primarily of sensory motor activities, such as running, jumping, and swinging. Alex enjoyed motor activities (running, jumping, etc), music, and playing outside. His mother reported that when he was frustrated, tired, or was separated from his mother, he cried, but when he was happy he had the same happy squeal for everything exciting in his life. Alex's psychologist noted that Alex seemed to have a social interest in people, but he had a difficult time engaging in social play and did not initiate or participate in acts of joint attention. Alex's mother reported that he frequently looked at her when she was talking to him, especially if she had been gone for awhile; however, he did not look at a person when they were pointing to an object, though he did occasionally look at the object. Overall, Alex was an affectionate child who enjoyed snuggling, hugging, or sitting on his parents' laps.

Education history. At the age of 10 months, Alex received early intervention services once a month. These services included speech, language, and physical therapy. Professionals providing these services followed a consultation intervention model, integrating parent education into Alex's treatment plan.

Alex began attending his school district's preschool for children with special needs in September, 2009. This preschool also included typically developing children. Alex initially had difficulty separating from his mother and adjusting to the preschool setting. Alex's teacher reported that he cried excessively, was frequently inconsolable, and did not participate in preschool routines. As a result, he attended preschool for only two of the four hours until January 2010. His initial negative reaction to school resulted in his peers avoiding social interaction with him and referring to him as *the baby.* Eventually his tolerance for school routines improved, and at the time of study Alex attended preschool four days per week for the entire four hours. Alex began to tolerate separation from his mother, cried less frequently, and began to exhibit an emerging awareness of and participation in school routines. As a result, his peers began to stop calling him *the baby*. Alex continued to ignore his peers' attempts to include him in social interactions, and did not initiate any interactions with peers; however, his teacher reported that Alex began observing his peers' social interactions and would frequently play alone near his peers, although he would not engage in interactions with them. Alex's social communication skills consisted of limited communication with his teachers in the form of non-verbal requests for a drink and a snack.

While attending the preschool, Alex also received speech and language services from the school SLP. His Individualized Education Plan (IEP) goals consisted of:

- Discriminating colors
- Discriminating shapes
- Demonstrating understanding of the concepts of *same* and *different*
- Improving his ability to initiate and maintain social interactions with his peers
- Demonstrating willingness to participate in structured classroom activities

- Improving receptive and expressive language skills through the use of words and signs
- Improving fine motor skills

Appendix A presents a list of Alex's specific IEP goals. In September, 2009, Alex's teacher rated his performance in the following areas: (a) general concepts, (b) math concepts, (c) speech and language, (d) attention and memory, (e) gross motor, (f) fine motor, (g) self-concept and self-help, (h) social play, (i) reasoning and responsibility, and (j) literacy. The rating scale used is as follows from lowest to highest: -, *E*-, *E*, *E*+, and +. A score of – means that the objective is absent while a score of + means the objective is mastered. A score of *E*- means that the objective is present but rare, a score of *E* means the objective is emerging and seen occasionally, and a score of *E*+ means that the objective is emerging and seen frequently. In May, 2010 Alex was reassessed using the same criteria and scale to determine progress. In September, 2009, Alex received a – on 64% of academic targets, and received a + on only 1% of academic targets. In May, 2010, Alex received a – on 44% of academic targets, and received a + on 3% of academic targets. Appendix B displays Alex's complete assessment results.

History of speech and language services. Data were gathered upon enrollment to the BYU Speech and Language Clinic to assess Alex's receptive language skills, expressive language skills, and his joint attention skills. Assessment included both formal and informal measures, consisting of the *Preschool Language Scale-4th Edition* (PLS-4), the *Westby Playscale*, and informal observation and language samples.

The PLS-4 was administered on March 13, 2009 by a graduate student not involved with this study. Alex scored 2.5 standard deviations below the mean in both auditory comprehension and expressive communication, placing him in the first percentile. On September 14, 2009, when Alex was 3:1 years, the *Westby Playscale* was administered by a graduate student not involved with the study. Results showed that Alex played at the Pre-symbolic Level II, which is typical of the play of a normally developing 13-17 month old child. Skills included demonstration of awareness of object permanence, the ability to dump toys out of a bottle, and the ability to operate simple toys. The *Westby Playscale* was re-administered on January 14, 2010 by a graduate student involved with the study. Results showed little change as Alex continued to play at the Pre-symbolic Level II.

Informal observation and language samples revealed that Alex's receptive language skills consisted of the ability to follow simple commands, such as *wait, hold hand,* and *stop* with verbal and tactile cues. However, he did not follow verbal commands without tactile cues. His expressive language skills consisted of the ability to spontaneously name the following letters: *E, Z, X, O,* and *L* in response to a visual prompt. He did not vocalize any words. Alex's joint attention skills consisted of the ability to participate in reciprocal activities (i.e., rolling a ball, playing with cars, playing with blocks, etc) for 7 to 10 minutes each. It was noted that Alex was able to attend to these activities, but behaviors of joint attention (eye contact, imitation, affect, etc) were not noted during the exchange.

At the age of 30 months, Alex began treatment at the BYU Speech and Language Clinic in May 2009, for speech, language, and social function delays secondary to PDD-NOS. Since beginning therapy at the BYU clinic, Alex's goals have consisted of; (a) improving his play skills by improving his ability to attend to interactive activities and by improving his ability to participate in symbolic play; (b) improving his joint attention skills by increasing frequency of eye contact, improving his ability to initiate activities, and by improving his ability to take turns; (c) improving his receptive language skills by improving his ability to comprehend simple commands, identify his family members' names, and identify common objects; and (d) improving his expressive language skills by increasing the appropriate use of the words *more* and *please*, improving his ability to use gestures as a form of communication, and increasing his use of simple and functional one-word utterances. Appendix C presents a list of the Alex's specific speech and language goals targeted during the fall 2009 semester at the BYU Speech and Language Clinic.

Prior to the study Alex demonstrated difficulty engaging in activities during therapy. Instead, Alex preferred to sit alone in a corner and rock or spin toys. Alex would engage in these behaviors for the entire 50-minute session if allowed to do so. Alex required excessive and constant prompting and sensory stimulation from the clinician in order to become engaged in a task. Once engaged Alex was able to attend to a task for approximately one minute before losing interest, at which point the clinician quickly introduced a new task in order to maintain some level of engagement. Parent education was a key goal of Alex's therapy; therefore, the clinician often educated Alex's mother on various treatment tasks. However, the clinician was required to choose carefully when to interact with Alex's mother during therapy because once the clinician's attention diverted from Alex, Alex became uninterested in the activity and was very difficult to reengage.

In November, 2009, data were gathered to assess Alex's receptive and expressive language skills, joint attention skills, and play skills. Alex's receptive language skills consisted of the ability to demonstrate the understanding of the commands *hold hand, sit down,* and *clean up* with visual support. Alex's expressive language skills consisted of the ability to imitate verbalizations of *L* and *F*, produce a vowel-like vocalization similar to *Y*, imitate the *H* sound, appropriately use the vocalization "mamama" for the word *more* with moderate support, and point with moderate support. Alex's joint attention skills consisted of the ability to attend to an interactive toy for 7 minutes with moderate support, and the ability to take one turn with no support during a motivating activity. Alex's play skills consisted of the ability to feed a doll with maximal hand-over-hand support.

Chris. Chris was an eight-year-old male born on March 7, 2002, who was identified with attention deficit hyperactive disorder (ADHD) at age 3. Later, Chris was diagnosed with ASD by a child psychologist in January, 2004, at the age of 48 months. At the time of this study, Chris was 7:11 years.

Birth and medical history and motor milestones. The following information was obtained through a case history report filled out by Chris's mother on August 16, 2006, when Chris was 48 months old.

Chris lived at home with his mother, father, older brother, and younger brother. His prenatal history was unremarkable, with gestation lasting 37 weeks and no reported complications. Chris was a healthy infant and toddler with no medical concerns except for frequent ear infections as a toddler that resulted in the placement of PE tubes at the age of 24 months. Chris's development consisted of sitting up at six months, crawling at eight months, and walking at nine months. Chris had normal hearing and took medication for ADHD at the time of the study.

Speech and language development. Chris's mother reported that he spoke his first words at 12 months. These words included *ball, mama,* and *uh-oh.* Chris's mother reported that he only used one word at the age of 48 months. His mother was unaware of any family history of ASD; however, she reported that Chris's older brother had speech articulation problems. In March, 2007, a local SLP not involved with this study administered the PLS-4. Chris scored three standard deviations below the mean in both auditory comprehension and expressive communication. At the time of the study, Chris communicated in short two to four word phrases, such as "I want juice, please." Chris could produce the word *please* independently, but needed prompting to produce full sentences. However, he did attempt to imitate many words.

Education history. Chris began receiving early intervention services in 2005, where intervention goals focused on following one-step directions, imitating words, increasing the ability to say his name correctly, answer yes/no questions about himself, and improve his ability to make requests. During the study, Chris attended a self-contained special education classroom at a local public elementary school, and received speech and language services from his school SLP. His IEP goals consisted of learning to write his name, address, and phone number, complete simple addition problems, read site words, improve reading comprehension, improve fine motor skills, verbally express wants and needs, produce CVC target words, and participate in classroom activities with fewer than five prompts. Appendix E presents a list of Chris's specific IEP goals.

History of speech and language services. Baseline data and follow-up data were gathered prior to the study to determine Chris's progress with regular intervention services over the course of two semesters. Baseline data were gathered at the beginning of Chris's first semester at the BYU Speech and Language Clinic in January, 2009. Follow-up data to assess Chris's progress at the BYU Speech and Language Clinic were gathered in June, 2009. Data were not gathered between July and December, 2009 as Chris was not seen in the clinic during that time.

In January, 2009, baseline data were gathered at the beginning of Chris's first semester at the BYU Speech and Language Clinic to assess his joint attention skills, play skills, and expressive language skills. Chris's joint attention skills consisted of making eye contact three times during a 50-minute session. In January, 2009, Chris did not participate in constructive or reciprocal play during a 50-minute session, nor did he use three-word utterances or make appropriate comments during a structured activity during a 50-minute session.

Chris began treatment at the BYU Speech and Language Clinic in September 2008 for speech, language, and social function delays secondary to ASD. Since coming to the clinic, Chris's goals have consisted of; (a) improving his level of engagement during activities with a conversational partner by increasing frequency of eye contact; (b) developing his ability to participate in constructive play by participating in reciprocal play; and (c) increasing his expressive language by using phrases to communicate wants and needs and making appropriate comments during structured activities. Appendix F presents a complete list of Chris's specific goals targeted at the BYU Speech and Language Clinic during the spring 2009 semester.

Prior to the study Chris consistently displayed difficulty with repetitive behaviors, over stimulation, and staying engaged and on-task throughout an activity during therapy. Chris repetitively manipulated toy LEGOS® and LEGO® men. Chris often brought one or more LEGO® men with him to therapy, which presented a unique challenge, as Chris would not participate in activities when he brought LEGO® men from home. Instead, Chris would walk around the room looking at and talking to his LEGO® man, ignoring his clinician's attempts to engage him in other activities. The clinician frequently attempted to involve use of the LEGO® man in activities in hopes that Chris would become engaged; however, this strategy was rarely effective. During sessions where Chris did not have LEGO® men, he was more easily, though inconsistently, engaged in activities. Chris easily became over stimulated, resulting in his bouncing and flapping his arms. Chris's clinician introduced large bean bags for Chris to sit on during the therapy session to help provide Chris with sensory input in a more socially appropriate manner. On rare occasion, Chris would engage in an activity with the clinician without excessive and constant prompting from the clinician. However, these episodes of engagement were rare and brief as Chris was highly distractible and required constant prompting to stay on task for more than two minutes.

In June, 2009, data were gathered to assess Chris's joint attention skills, play skills, and expressive language skills. Chris's joint attention skills consisted of the ability to make appropriate eye contact eight times with his clinician during a 50-minute session. Chris's play skills consisted of seven instances of imitating his clinician's model, and one instance of initiating reciprocal play. Chris's expressive language skills consisted of Chris using nine three-word phrases to communicate preferences, and making 21 appropriate comments during three structured activities within a 50-minute session.

Procedures

This study was part of a larger pilot study exploring the use of robots to facilitate engagement and joint attention in children with ASD. During the study, a 10-15 minute interaction with a humanoid robot named Troy was added to the participants' regular treatment sessions. The robot was introduced to each child and the clinician then engaged the child in a series of reciprocal games and activities involving the robot, the clinician, the child, and a parent when available.

Data for this study were gathered from four assessments that were administered both pre and post treatment. These assessments were labeled *child-parent play assessment, child-clinician play assessment, unfamiliar adult play assessment,* and *triadic interaction assessment.* For the purposes of this study, only the *child-parent play assessment* and the *child-clinician play* *assessment* were considered. Specific behaviors were identified, including acts of *language, affect, imitation,* and *eye contact* in the categories of *Initiating Engagement* and *Responding to Engagement.* Act of *language, affect, imitation,* and *eye contact* were identified and quantified within these sessions as described in the Data Analysis section. In addition to the results of this study, several clinical observations were noted describing behaviors that were not captured by the data analysis system. These behaviors included the participants' acclimation to and interest in the robot, observed effects of the interaction with the robot on intervention conducted without the robot, and changes in the participants' restricted interests and repetitive play.

Pre-treatment data. Baseline levels of joint attention were assessed during two free-play periods. Chris's assessments were administered over two consecutive sessions and Alex's assessments were gathered over a two-week period. Each session was audio and video recorded for analysis. Two cameras were used to record each interaction. The first was a Network Camera™, which was mounted on the wall opposite where Troy was placed, providing a front-view of Troy and a back-view of the child. The second camera was a Canon™ digital, hand-held camera which was operated by a university student seated near the wall opposite the mounted camera, providing a front-view of the child and a back-view of Troy. Alex's mother was in the therapy room during the assessments because he did not tolerate separation from her; however, she was not actively involved in the play interactions during the assessments.

Child-parent play assessment. The child-parent play assessment consisted of evaluation of play behaviors during interaction between the child and his parent and was patterned after a child-parent play assessment reported by Kasari, Freeman, and Paparella (2006). The purpose of this assessment was to determine the amount of joint attention behaviors the child produced during a play interaction with his parent. The child and his parent were left alone in a therapy room for 20 minutes with the following toys: two trucks, a bus, a fire truck, two helicopters, play food, dishes, dolls, a puzzle, and blocks. Each parent was instructed to play with their child as they normally would while using the toys provided.

Child-clinician play assessment. The child-clinician play assessment evaluated play behaviors during interaction between the child and his graduate clinician. This assessment was patterned after a child-clinician play assessment designed by Kasari et al. (2006). The purpose of this assessment was to examine joint attention behaviors the children produced during a play interaction with their clinicians. The child and clinician interacted in a therapy room for 20 minutes with the following toys: three dolls, doll accessories, baby bottles, a tea set, a dump truck, a car garage, two toy cars, wood blocks, a telephone, a hair brush, and a mirror. First, the clinician handed the child a toy and then observed how the child played with the toy. If the child played with the toy appropriately, the clinician commented on the child’s play and attempted to enter the child’s play to elicit joint attention behaviors. If the child did not play with the toy appropriately, the clinician modeled appropriate play with the toy, and then let the child try again. Once the child had attempted to play with the toy by himself, the clinician attempted to insert herself into the child’s play in order to elicit joint attention behaviors. An example dialogue of this interaction is provided in Table 1.

Treatment. During the study each child received speech and language intervention services at the BYU Speech and Language Clinic over the course of a semester. Treatment consisted of two 50-minute sessions per week for 15 weeks. A total of 20 treatment sessions were provided throughout the course of the study: two pre-treatment data sessions, 16 treatment sessions, and two post-treatment data sessions. It was noted that some sessions were canceled due to child illness and holidays, but these sessions were made-up in subsequent weeks.

Table 1

Example of an Interaction during the Child-Clinician Play Assessment

Clinician Action	Clinician Comment	Child Action
Clinician presents Alex with a toy baby and observes as Alex plays with the toy.	"Oh, a baby doll!"	Child does not play with toy appropriately, but instead, bangs the baby on the table.
Clinician takes the baby and demonstrates how to hold and feed the baby. Clinician hands the baby back to the child.	"Watch me."	Child begins playing with the doll appropriately by imitating the clinician's example of feeding and holding the baby.
Clinician comments on child's appropriate play.	"Oh, you feed the baby! Alex feeds the baby."	Child continues to play with the doll and show interest in the interaction.
Clinician attempts to enter child's play.	"Look, I feed the baby. Gulp, gulp. Oh, hungry baby!"	Child continues to interact with clinician.

Forty minutes of each therapy session consisted of regular speech and language therapy previously implemented for these children at the clinic. Treatment was family oriented, naturalistic, and largely child-centered. The clinician manipulated the environment to encourage the child to produce specified targets. Since child engagement was the key goal of therapy, the clinician followed the child's lead whenever appropriate.

Ten minutes of each session consisted of experimental therapy with the robot. The child, his graduate clinician, and an assisting graduate clinician were involved with the activities; joint attention was targeted during this segment of the treatment session. The child's clinician and his parent (when available) engaged in a triadic or quadratic interaction with the child and the robot, while the assisting clinician helped the child interact with his clinician and the robot with hand-over-hand prompts. Before each session, timing of the robot activity was randomly chosen to be at the beginning, middle, or end of the therapy session.

Troy: the robot. The robot, Troy, was a humanoid robot created by graduate students from the Brigham Young University Department of Mechanical Engineering. He was designed to be used in a clinical therapy session for children with ASD to help target joint attention skills. As such, he was designed to produce specific human movements of the arms and neck, basic facial expressions, and verbal songs and phrases that would contribute to reciprocal interaction. Figure 1 displays a photograph of Troy's facial expressions: sad, neutral, and happy.

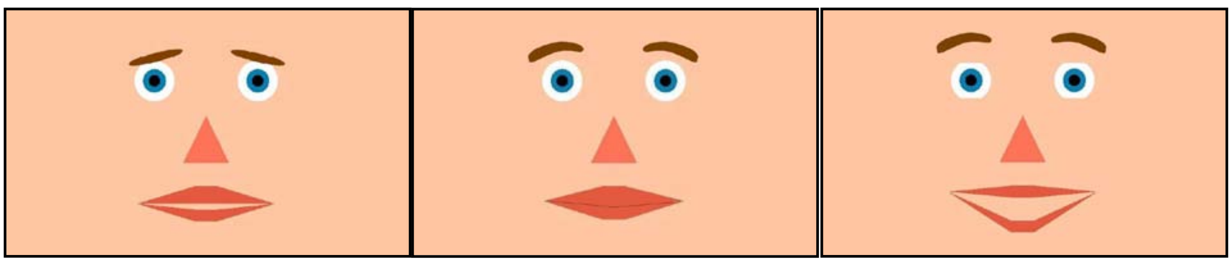

Figure 1. Picture of Troy's facial expressions. From left to right: sad, neutral, happy. Adapted from "Design and Evaluation of a Humanoid Robot for Autism Therapy," by Daniel Ricks, 2010, Brigham Young University, Provo. Reprinted with permission.

Design. Troy was an upper-body, humanoid robot. Only his upper body was actuated, and he was designed with human attributes. He consisted of a 9x11 inch base, a trunk, two arms, a neck, and a head. Troy was designed to approximate the size of an average 3-4 year old child; thus, he was approximately 25 inches tall from his base to the top of his head, and his arms were approximately 12 inches in length. Pictures of Troy are provided in Figure 2 (Ricks, 2010).

Figure 2. Picture of the front, side, and back view of Troy. Adapted from “Design and Evaluation of a Humanoid Robot for Autism Therapy,” by Daniel Ricks, 2010, Brigham Young University, Provo. Reprinted with permission.

Troy’s neck, shoulders, and arms were actuated using RC servo motors. Each of Troy’s arms contained four degrees of freedom for movement: one for shoulder flexion/extension, one for shoulder abduction/adduction, one for humeral rotation, and one for elbow extension/flexion. This allowed Troy to perform simple actions such as pushing a car, tapping a tambourine, waving hello, etc. Troy’s neck was designed to move anteriorly, posteriorly, and laterally, which gave him the ability to look at the individual he was speaking to. Figure 3 shows all of Troy’s possible movements. During the session, the clinician used these features to manipulate Troy in order to provide opportunities for the child to request or initiate activities (Ricks, 2010).

Troy also contained a speaker connected to a laptop through a USB port. Sounds and phrases were recorded in a computer and played through Troy’s speaker, giving Troy the ability to produce any desired phrase or sound. A student majoring in Music Dance Theatre recorded phrases such as *Hi Alex* and *Uh-oh*, and songs such as *Popcorn Popping on the Apricot Tree* and

Three Little Monkeys Swinging in the Tree. These phrases and songs were programmed into the computer and used during the activities (Ricks, 2010).

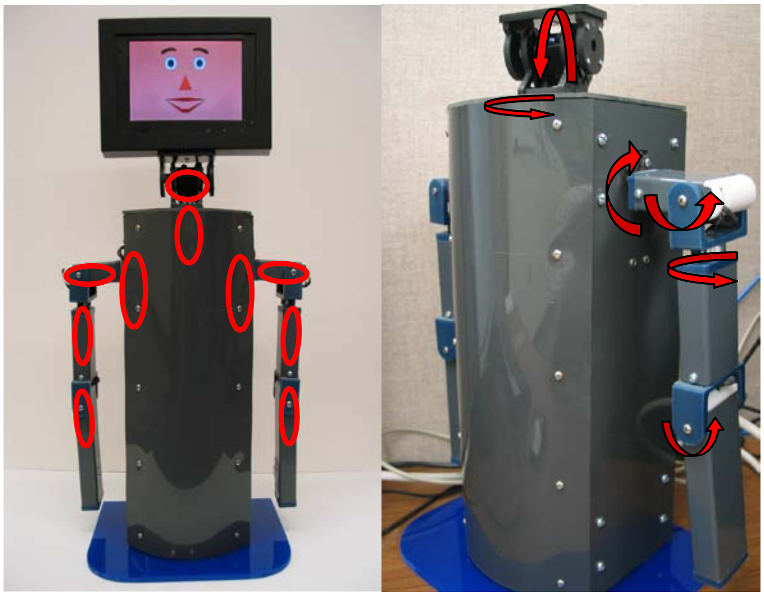

Figure 3. Picture of Troy's motor locations and direction of rotation. Adapted from "Design and Evaluation of a Humanoid Robot for Autism Therapy," by Daniel Ricks, 2010, Brigham Young University, Provo. Reprinted with permission.

Software and control. Troy was powered through an outlet and was controlled through a graphical user interface, which was installed on a laptop in the therapy room. The interface provided a simple visual programming system to allow the clinicians to control and change the movements of the robot. Specific actions, sounds, and facial expressions were pre-programmed onto the interface, which could then be dragged and dropped onto a screen to create a desired sequence. Any number of desired sequences could be pre-created and saved to be used for future therapy sessions. An example of the interface is provided in figure 4 (Ricks, 2010).

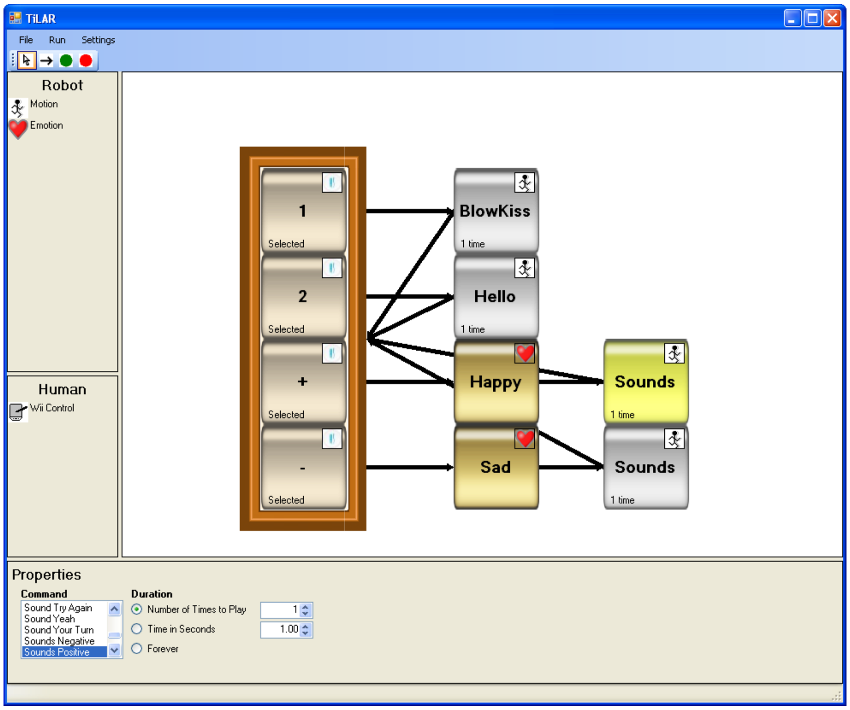

Figure 4. Picture of an example screen of the user interface. Adapted from "Design and Evaluation of a Humanoid Robot for Autism Therapy," by Daniel Ricks, 2010, Brigham Young University, Provo. Reprinted with permission.

To provide the clinicians with further ease of control over the use of the robot, a Wii™ remote was connected to the computer interface through Bluetooth technology. Any action, sound, facial expression, or sequence could be programmed into the buttons of the Wii™ remote. During the session, the clinicians used the Wii™ remote to control Troy, providing a far easier and less distracting means of control than use of a laptop computer. Further, the Wii™ remote allowed the clinicians to control Troy without the participants' knowledge. Thus, to Alex and Chris, Troy engaged in activities of his own accord (Ricks, 2010).

Protocol. A protocol of interactive activities was designed to guide the activities and create opportunities for joint attention during the robot activity. The protocol was used as a guideline to encourage the child to initiate and request acts of joint attention, but the clinicians followed the child's lead whenever an opportunity arose in order to create a joint attention interaction in a natural context. The protocol consisted of reciprocal turn-taking sequences meant to integrate affect into a social exchange. These routines were initiated by the clinician, Troy, or the child, and rotated among the three partners. Occasionally, activities within the routines were purposefully unsuccessful in order to make the activity more naturalistic, encourage the use of a range of affect, and build contrast into the exchange. Both positive and negative affect were used and encouraged in order to make the exchanges more engaging. Regardless of whether the activities within the routine were successful or not, each routine ended with positive affect in order to encourage the participants to engage in future routines. An example of a clinician-initiated routine is as follows:

1. Clinician performs the action

2. Robot performs the action (Clinician displays positive affect such as, "Hooray!")

3. Child performs the action (Clinician and robot display positive affect)

An example of a routine initiated by Troy is as follows:

1. Troy performs the action

2. Child performs the action (Clinician and robot display positive affect)

3. Clinician performs the action (Clinician and robot display positive affect)

An example of an unsuccessful clinician-initiated routine is as follows:

1. Clinician performs an action

2. Robot fails to perform the action or performs it incorrectly

3. Clinician reacts and requests the robot to try again (Clinician displays negative affect such as, "Oh, too bad," or "Try again!")

4. Robot correctly performs the action (Clinician displays positive affect)

5. Child performs the action (Clinician and robot display positive affect)

Appendix H presents a detailed description of the protocol. Table 2 provides an example dialogue of a typical protocol routine.

Table 2

Example Dialogue of Troy Initiating a Protocol Routine

Communicative Partner	Comment	Action
Troy	"Hi Chris!"	Troy waves to Chris
Chris	"Hi Troy."	Chris waves to Troy
Clinician	"Hi Chris!"	Clinician smiles and waves to Chris
Chris	"Hi"	Chris waves to clinician spontaneously or with hand-over-hand support from the assisting clinician
Clinician	"Hi Troy!"	Clinician smiles and waves to Troy
Troy	"Hi"	Troy waves to clinician

Alex's treatment sessions. Alex's treatment included two 50-minute sessions per week with a graduate clinician who implemented a family centered, naturalistic, interactive, and child-centered therapy model during these sessions. The sessions are described in detail in a later section. As Alex was still very young, his mother attended all of his therapy sessions and was included in therapy activities, including assessment and therapy sessions involved with the robot. Alex's infant sister was also present during a majority of the sessions as she was too young to be left alone. She was generally napping during the sessions, however.

Forty minutes of regular therapy. During the 40 minutes of regular therapy, the following goals were addressed using a naturalistic, interactive, and child-centered therapy model: (a) improving Alex's play skills by facilitating his ability to attend to interactive activities and by encouraging his participation in symbolic play; (b) improving his joint attention skills by increasing frequency of eye contact, improving his ability to initiate activities, and by enhancing his ability to take turns; (c) improving his receptive language skills by facilitating his ability to comprehend simple commands, identify his family member's names, and identify common objects; and (d) improving his expressive language skills by increasing the appropriate use of the words *more* and *please*, improving his ability to use gestures as a form of communication, and increasing his use of simple and functional one-word utterances. Appendix D presents a complete list of Alex's treatment goals targeted during this study.

Each session consisted of a picture schedule, a table activity, a motor activity, and a play activity. The picture schedule was used to help orient Alex to the sequence of the session and was used to teach Alex the concept that pictures represent objects. The picture schedule included a picture of the table in the therapy room, a picture of Troy, a picture of materials used during motor activities, and a picture of materials used during play activities. The table activity usually consisted of reading a book to help increase Alex's attention span and to familiarize him with the names of common animals. The table activity also included identifying Alex's individual family members from their photographs. This activity was used to help Alex learn the concept that a picture represents an object, learn to point, and learn the names of his family members. Motor activities included hopping on carpet squares and running around the therapy room to help Alex regulate and gain sensory input. Play activities included participating in symbolic play with various toys, such as a kitchen set, cars, a car garage, blocks, a bowling set, and a baby doll. These activities were designed to teach Alex how to play appropriately.

Ten minute robot segment. During the ten-minute robot segment of the session, joint attention was targeted by using the previously described protocol. During this segment, Alex, his clinician, Troy, and Alex's mother engaged in a quadratic interaction during various activities. An assisting graduate clinician sat behind Alex and provided hand-over-hand support and modeled appropriate responses during the interaction. The robot activity always began with a greeting segment, where Alex, Troy, Alex's mother, and the clinician waved and said *hi* to each other. Next, Alex, Troy, Alex's mother, and the clinician jointly played with a toy. These toys included balls, a bowling set, a truck, and a tambourine. Next, Alex, Troy, Alex's mother, and the clinician sang a song together. Songs included *Popcorn Popping on the Apricot Tree* and *Three Little Monkeys Swinging in the Tree.* The activity ended with a farewell segment where Alex waved and said good-bye to Troy and the assisting clinician. Table 3 provides an example dialogue of a typical robot therapy segment.

Chris's treatment sessions. Chris's treatment included two 50-minute sessions per week with a graduate clinician who implemented a family centered, naturalistic, interactive, and child-centered therapy model during these sessions. The sessions are described in detail later. Chris's siblings were occasionally present during his sessions and were involved in helping Chris generalize his goals and regulate inappropriate behaviors.

Forty minutes of regular therapy. During the 40 minutes of regular speech and language therapy, the following goals were addressed using a naturalistic, interactive, and child-centered therapy model: (a) improving Chris's level of engagement during activities with a conversational

Table 3

Example Dialogue of a Typical Robot Therapy Segment

Activity	Dialogue	Action
Greeting	T: "Hi Alex!"	Troy waves to Alex
	C2 or A: "Hi Troy."	Alex waves to Troy
	C1: "Hi Alex!"	Clinician waves to Alex
	C2 or A: "Hi!"	Alex waves to clinician spontaneously or with hand-over-hand support from the assisting clinician
	C1: "Hi Mom!"	Clinician waves to Alex's mother.
	M: "Hi Alex!"	Alex's mother waves to Alex.
	C2 or A: "Hi Mom!"	Alex waves to his mother spontaneously or with hand-over-hand support from the assisting clinician.
Toy	C1: "Let's push the truck! Push to Troy!"'	Clinician pushes the truck to Troy.
	C1: "Troy push to Alex."	Troy pushes the truck to the Alex.
	C1: "Yay, way to go Troy!" C2 or A: "Wo-hoo!" C1: "Alex, push to me!"	Alex pushes truck to clinician spontaneously or with hand-over-hand support from the assisting clinician.
	C1: "Yay, thank you! I push to Alex."	Clinician provides affect response to Alex's participation and pushes truck to Alex.
	C1: "Wo-hoo, you got it! Alex push to Mom!"	Alex pushes truck to Mom spontaneously or with hand-over-hand support from the assisting clinician.
Song	C1: "Troy sing song?" C2 or A: "Yeah!"	Troy sings *Popcorn Popping on the Apricot Tree* with actions.
	C1: "Wow, way to go Troy! I sing song."	Clinician sings *Popcorn Popping on the Apricot Tree* with actions.
	C1: "Alex sing song!"	Assisting clinician sings *Popcorn Popping on the Apricot Tree* while providing hand-over-hand support for actions.
	C1: "Yeah Alex! Mama sing song!"	Alex's mother sings *Popcorn Popping on the Apricot Tree* with actions.
Good-bye	C1: "Bye-bye Troy!"	Clinician waves to Troy.
	T: "Bye!"	Troy waves to Alex.
	C2 or A: "Bye Troy."	Alex waves to Troy.
	C1: "Bye Alex!"	Clinician waves to Alex.
	C2 or A: "Bye-bye!"	Alex waves to clinician spontaneously or with hand-over-hand support from the assisting clinician.
	T: "Bye."	Troy waves to Alex's mother.
	M: "Bye Troy!"	Alex's mother waves to Alex.

partner by increasing frequency of eye contact; (b) developing his ability to participate in constructive play by participating in reciprocal play; and (c) increasing his expressive language by using phrases to communicate wants and needs, and making appropriate comments during structured activities. Appendix G presents a complete list of Chris's treatment goals targeted during the study.

Each session consisted of a picture schedule, a motor activity, a snack, a book, and a play activity. The picture schedule was a numbered sequence schedule with the pictures of the activity hidden underneath the number. The picture of the activity was revealed at the beginning of each activity. The picture schedule was used to help orient Chris to the sequence of the session and to help him visualize the amount of time remaining in the session. The motor activity always consisted of pushing a bin down the hall to his treatment room, and was used to provide sensory input and to help Chris regulate his behavior. Snack usually consisted of gold fish and a juice box and was used to encourage Chris to request items he desired. The book activity consisted of Chris and his clinician reading a book together. The books chosen were tightly framed events with repetitive phrases to increase predictability and support comprehension. The books were used to help Chris participate in joint attention behaviors and learn new phrases. The play activity consisted of various activities such as LEGOS®, cars, tool sets, bowling, and a bean bag toss. These activities were used to help Chris engage in joint attention and to teach Chris how to participate in symbolic play.

Ten minute robot segment. During the ten-minute robot segment, joint attention was targeted by using the previously described protocol. During this segment, Chris, his clinician, and Troy engaged in a triadic interaction during various activities. An assisting graduate clinician sat behind Chris to provide hand-over-hand support and model appropriate responses during the interaction. The robot activity always began with a greeting with Chris, the clinician, and Troy waving and saying hi to each other. Next, Chris, the clinician, and Troy jointly played with a toy. These toys included trucks, LEGO® men, bowling set, fishing set, and balls. Next, Chris, the clinician, and Troy sang songs together. These songs included *Popcorn Popping on the Apricot Tree* and *Three Little Monkeys Swinging in the Tree*. Occasionally, the activities included facial expression imitation games, where Troy would display a facial expression and Chris and his clinician would imitate Troy or display different expressions for Troy to imitate. Each robot activity ended with a farewell segment, where Chris waved and said good-bye to Troy and the assisting clinician. Table 3 provides an example dialogue of a typical robot therapy segment.

Post-treatment data. After the 16 treatment sessions were completed, follow-up data were taken. Data were gathered over two consecutive sessions with the same two assessments that were administered during the pre-treatment assessment: the child-parent play assessment and the child-clinician play assessment. The assessments were conducted exactly as they were conducted during the pre-treatment assessments. All individuals, toys, and procedures used in the baseline assessments were used in the follow-up assessments.

Data Analysis

Data gathered during the pre and post treatment assessments were analyzed using a data analysis system patterned after the work of Kasari et al. (2006). Target behaviors included the presence of *language*, *affect*, *imitation*, and *eye contact* while the child initiated or responded to engagement. Due to the nature of the assessments, however, the data analysis system was altered to meet the needs of this study. Frequency of target behaviors were analyzed. Interjudge agreement was established at 91% for all categories prior to data analysis. In order to establish reliability, each assessment was coded in 5-second segments. Any target behaviors noted in each 5-second segment were coded. For example, if the child made eye contact with a communicative partner and displayed behaviors of affect during one 5-second segment, both *eye contact* and *affect* were coded for that segment. Figure 5 presents a diagram of the data analysis system.

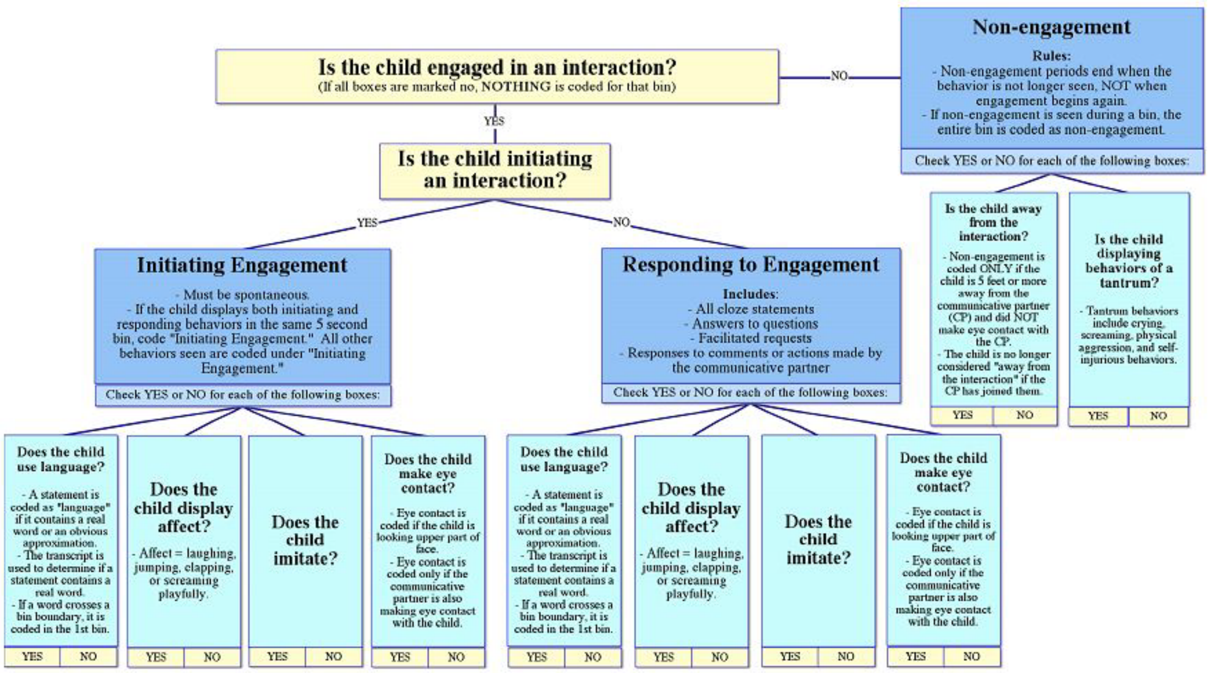

Figure 5. Flow chart for the data analysis system.

Analyzed behaviors were separated into one of three main categories: *Initiating Engagement*, *Responding to Engagement*, and *Non Engagement*. Segments that did not contain behaviors of engagement or non engagement were coded as *nothing*. Behaviors were coded under *Initiating Engagement* if the child spontaneously displayed behaviors, rather than if the child displayed behaviors in response to an action or language bid from a communication partner. If a behavior was coded under *Initiating Engagement*, all other behaviors noted in that same 5-second segment were coded under *Initiating Engagement*, even if a noted behavior was in response to a communicative partner's action. Thus, it was possible to code a behavior as *imitation* under *Initiating Engagement*, even though imitating behaviors are responsive in nature. Behaviors were coded under *Responding to Engagement* if the child displayed the behaviors in response to an action or bid from a communication partner. All responses to cloze statements, questions, comments, and facilitated requests were coded under *Responding to Engagement*.

The categories of *Initiating Engagement* and *Responding to Engagement* each contained four behaviors associated with social engagement: (1) *language*, (2) *affect*, (3) *imitation*, and (4) *eye contact*. A statement was coded as *language* if it contained a real word or an obvious approximation of a real word. Verbalizations and vocalizations were not coded as *language* if they could not be identified as a word with communicative intent. All of the pre and post data assessments were transcribed by graduate students unaffiliated with the study. These transcripts were used to determine if a statement contained a real word or an approximation of a real word. A behavior was coded as *affect* if the child displayed at least one of the following actions: laughing, jumping, clapping, or playfully screaming. A behavior was coded as *imitation* if the child imitated or repeated a communicative partner's action or vocalization. *Eye contact* was coded if the child looked at the upper part of a communication partner's face and if the communication partner looked back at the child.

Behaviors that indicated the child was not engaged in an activity with a communication partner were identified and coded under the main category of *Non Engagement*. *Non Engagement* contained two behaviors: (1) *away from the interaction* and (2) *tantrum*. A behavior was coded as *away from the interaction* if the child physically left an interaction, was more than five feet away from the communicative partner, and did not make eye contact with the communicative partner. A behavior was coded as *tantrum* if the child cried, screamed, or displayed physically aggressive or self-injurious behaviors. If behaviors of *Non Engagement* were seen during a 5-second segment, the entire segment was coded as *Non Engagement*, and any noted behaviors of engagement were not coded during that segment. Behaviors were no longer coded under *Non Engagement* once the child stopped demonstrating the behaviors, rather than when the child began demonstrating behaviors of engagement.

Results

Pre and post assessments for both participants were compared and frequency of target behaviors and duration of the assessments were analyzed. Since the communication partners followed the child's lead to determine the length of each assessment, the assessment continued for as long as the child was engaged in the interaction. The results of both the *child-parent play* assessments and the *child-clinician play* assessments are discussed below. For each assessment, Chris's pre and post results are discussed for each main category (*Initiating Engagement, Responding to Engagement,* and *Non-Engagement*), followed by a discussion of Alex's pre and post treatment assessment results for each main category. Finally, results of clinical observations are reviewed.

Play Assessments

Child-parent play assessment. Results of Chris's pre- and post treatment *child-parent play* assessments are presented in Table 4. Chris and his parent participated in the *child-parent play* pre-treatment assessment for a total of 10 minutes and 30 seconds. They participated in the *child-parent play* post treatment assessment for a total of 10 minutes and 50 seconds, which was 20 seconds longer than the pre-treatment assessment. Figure 6 presents the length of Chris's *child-parent* pre and post treatment assessments as well as the duration of engagement during the pre and post treatment *child-parent* assessments.

Table 4

Chris's Results for the Child-Parent Play Assessment

	Initiating engagement				Responding to engagement				Non Engagement	
	Lang	Affect	Imitation	EC	Lang	Affect	Imitation	EC	Away from Interaction	Tantrum
Pre-Tx	17	0	0	1	33	0	8	3	22	0
Post Tx	8	0	0	0	20	1	5	11	13	0

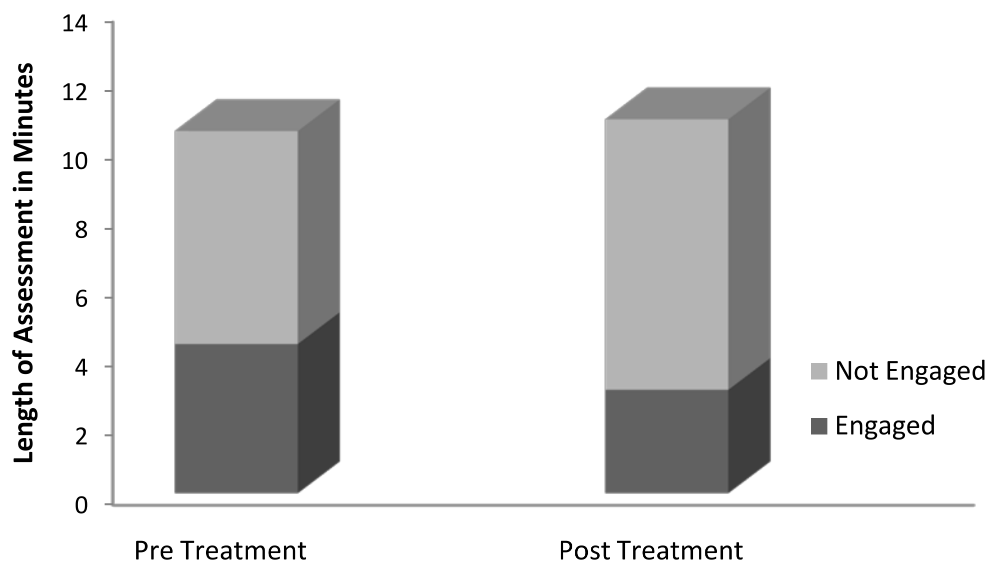

Figure 6. Length of the assessment and length of engagement versus non-engagement in minutes and for Chris's pre and post *child-parent* assessments.

Results showed that during the pre-treatment *child-parent play* assessment, Chris demonstrated a total of 18 instances of *Initiating Engagement:* 17 instances of *language,* no instances of *affect,* no instances of *imitation,* and one instance of *eye contact.* Chris demonstrated behaviors of *Initiating Engagement* for a total of one minute and 25 seconds (14%) of the assessment during the pre-treatment *child-parent play* assessment. During the post treatment *child-parent play* assessment, Chris demonstrated a total of eight instances of *Initiating Engagement:* eight instances of *language,* no instances of *affect,* no instances of *imitation,* and no instances of *eye contact.* Chris demonstrated behaviors of *Initiating Engagement* for a total of 40 seconds (6%) of the post treatment *child-parent play* assessment. Figure 7 presents the frequency of *Initiating Engagement* behaviors during Chris's pre and post *child-parent* assessment.

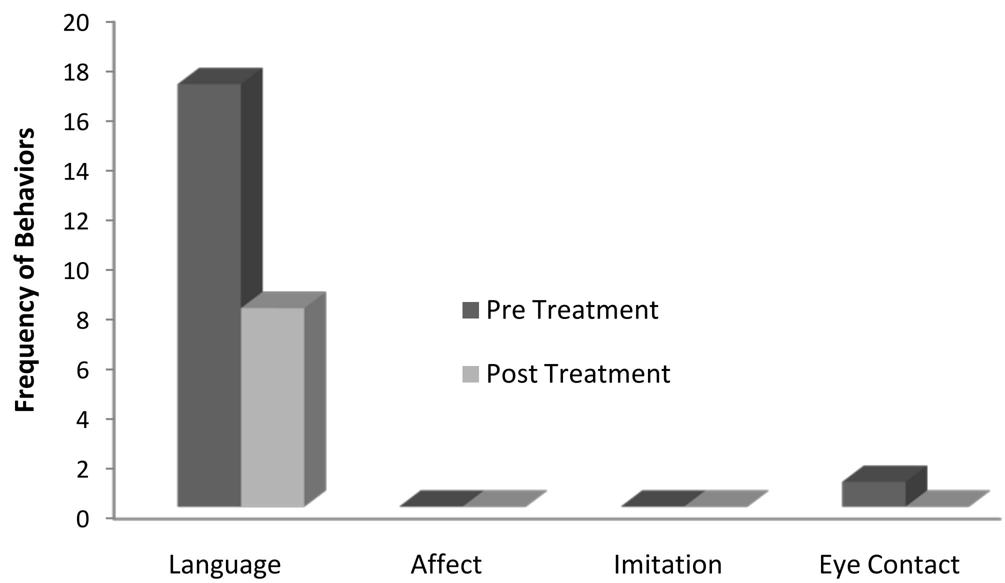

Figure 7. Number of *Initiating Engagement* behaviors coded for Chris's pre and post *child-parent* assessments.

During the *child-parent play* pre-treatment assessment, Chris demonstrated a total of 44 instances of *Responding to Engagement:* 33 instances of *language,* no instances of *affect,* eight instances of *imitation,* and three instances of *eye contact.* Chris demonstrated behaviors of *Responding to Engagement* for a total of two minutes and 55 seconds (28%) of the pre-treatment *child-parent play* assessment. During the post treatment *child-parent play* assessment, Chris demonstrated a total of 37 instances of *Responding to Engagement:* 20 instances of *language,* one instance of *affect*, five instances of *imitation*, and 11 instances of *eye contact.* Chris demonstrated behaviors of *Responding to Engagement* for a total of two minutes and 20 seconds (22%) of the post treatment *child-parent play* assessment. Figure 8 presents the frequency of *Responding to Engagement* behaviors during Chris's pre and post *child-parent* assessment. During the pre-treatment *child-parent play* assessment, Chris either initiated or responded to engagement in an activity with his parent for a total of four minutes and 20 seconds (42%) of the assessment. During the post treatment *child-parent play* assessment, Chris either initiated or responded to engagement in an activity with his parent for a total of three minutes (28%) of the assessment.

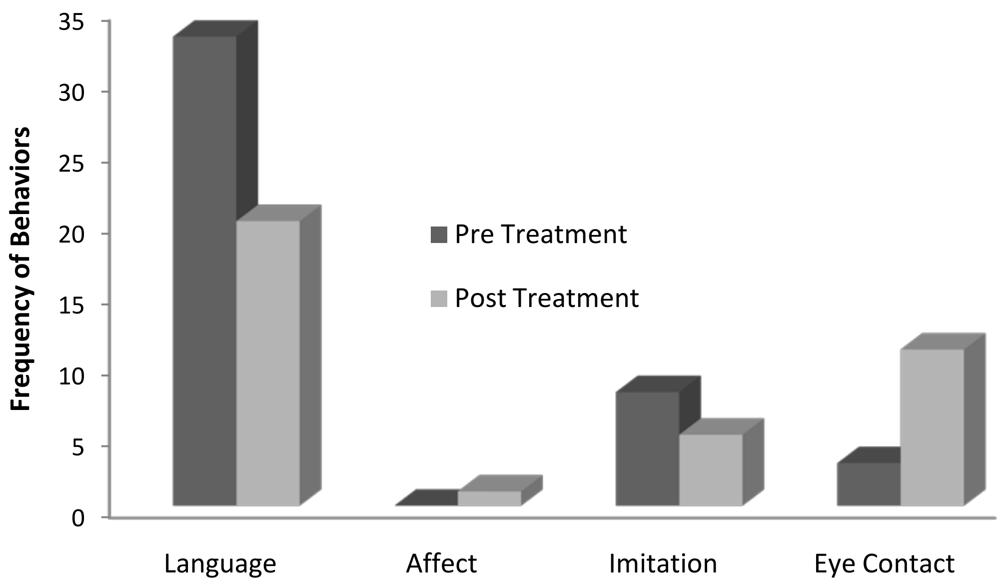

Figure 8. Number of *Responding to Engagement* behaviors coded for Chris's pre and post *child-parent* assessments.

During the *child-parent play* pre-treatment assessment, Chris demonstrated a total of 22 instances of *Non Engagement:* 22 instances of *away from interaction,* and no instances of *tantrum.* Chris demonstrated behaviors of *Non Engagement* for a total of one minute and 50 seconds (18%) of the pre-treatment *child-parent play* assessment. During the *child-parent play* post treatment assessment, Chris demonstrated a total of 13 instances of *Non Engagement:* 13 instances of *away from interaction,* and no instances of *tantrum.* Chris demonstrated behaviors of *Non Engagement* for a total of one minute and 5 seconds (10%) of the post treatment *child-parent play* assessment. Figure 9 presents the frequency of *Non Engagement* behaviors during Chris's pre and post *child-parent* assessment.

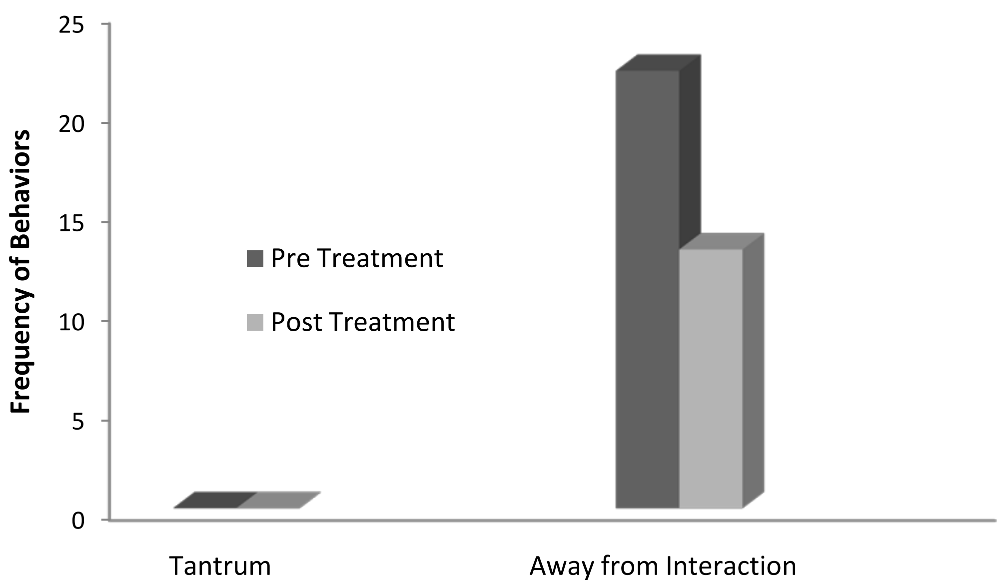

Figure 9. Number of *Non Engagement* behaviors coded for Chris's pre and post *child-parent* assessments.

Results of Alex's pre and post treatment *child-parent play* assessments are presented in Table 5. Alex and his parent participated in the *child-parent play* pre-treatment assessment for a total of 16 minutes and 50 seconds. They participated in the *child-parent play* post treatment assessment for a total of 18 minutes and 45 seconds, which was one minute and 55 seconds longer than the pre-treatment assessment. Figure 10 presents the length of Alex's *child-parent* pre and post treatment assessments as well as the duration of engagement during the pre and post treatment *child-parent* assessment.

Table 5

Alex's Results for the Child-Parent Play Assessment

	Initiating engagement				Responding to engagement				Non Engagement	
	Lang	Affect	Imitation	EC	Lang	Affect	Imitation	EC	Away from Interaction	Tantrum
Pre-Tx	0	0	0	3	3	8	3	6	39	1
Post Tx	5	3	6	15	36	19	38	18	13	0

During the *child-parent play* pre-treatment assessment, Alex demonstrated a total of 3 instances of *Initiating Engagement:* no instances of *language*, no instances of *affect,* no instances of *imitation,* and three instances of *eye contact.* Alex demonstrated behaviors of *Initiating Engagement* for a total of 15 seconds (2%) of the pre-treatment *child-parent play* assessment. During the *child-parent play* post treatment assessment, Alex demonstrated a total of 29 instances of *Initiating Engagement:* five instances of *language,* three instances of *affect*, six instances of *imitation,* and 15 instances of *eye contact.* Alex demonstrated behaviors of *Initiating Engagement* for a total of one minute and 15 seconds (7%) of the post treatment *child-*

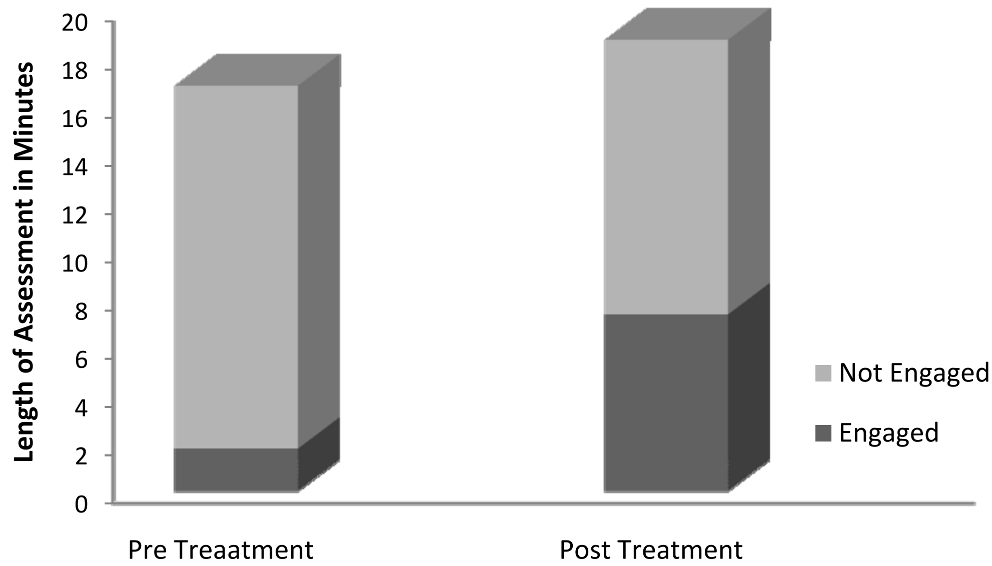

Figure 10. Length of the assessment and length of engagement versus non-engagement in minutes and for Alex's pre and post *child-parent* assessments.

parent play assessment. Figure 11 presents the frequency of *Initiating Engagement* behaviors during Alex's pre and post *child-parent* assessment.

During the *child-parent play* pre-treatment assessment, Alex demonstrated 20 total instances of *Responding to Engagement:* three instances of *language,* eight instances of *affect,* three instances of *imitation,* and six instances of *eye contact.* Alex demonstrated behaviors of *Responding to Engagement* for a total of one minute and 30 seconds (9%) of the pre-treatment *child-parent play* assessment. During the *child-parent play* post treatment assessment, Alex demonstrated a total of 111 instances of *Responding to Engagement:* 36 instances of *language,* 19 instances of *affect,* 38 instances of *imitation,* and 18 instances of *eye contact.* Alex demonstrated behaviors of *Responding to Engagement* for a total of six minutes and 5 seconds (32%) of the post treatment *child-parent play* assessment. Figure 12 presents the frequency of

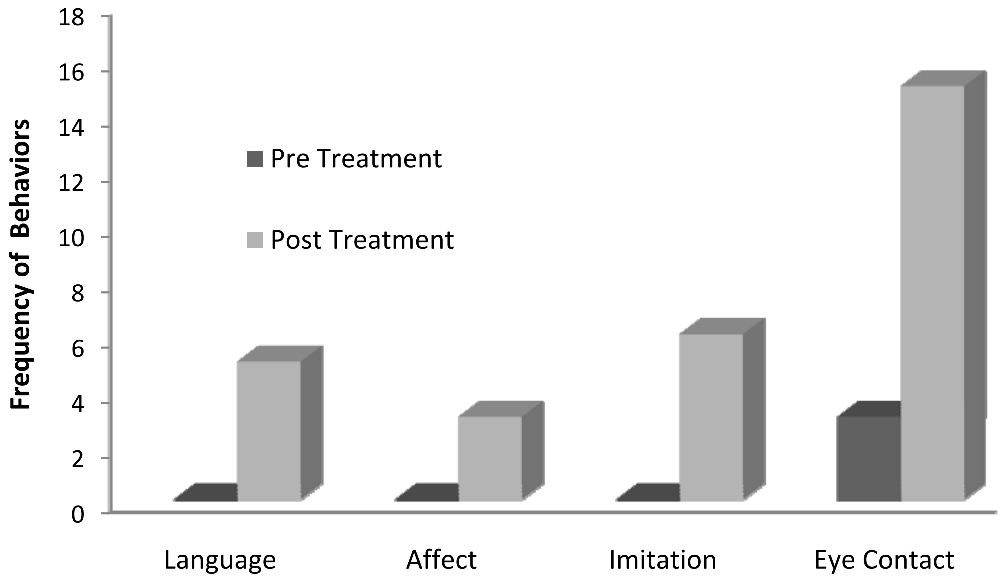

Figure 11. Number of *Initiating Engagement* behaviors coded for Alex's pre and post *child-parent* assessments.

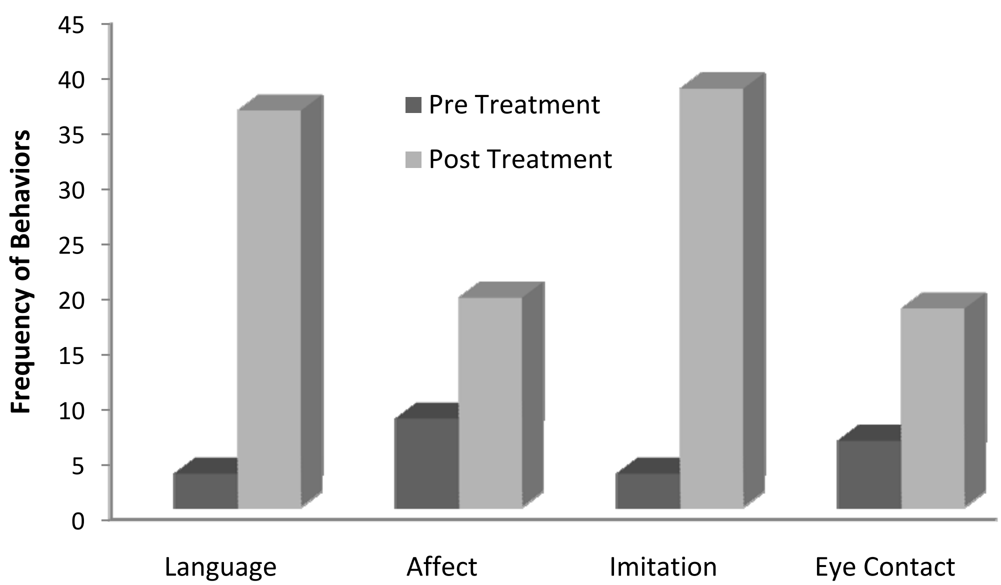

Figure 12. Number of *Responding to Engagement* behaviors coded for Alex's pre and post *child-parent* assessments.

Responding to Engagement behaviors during Alex's pre and post *child-parent* assessments. During the *child-parent play* pre-treatment assessment, Alex either initiated or responded to engagement in an activity with his parent for a total of one minute and 45 seconds (11%) of the assessment. During the *child-parent play* post treatment assessment, Alex either initiated or responded to engagement in an activity with his parent for a total of seven minutes and 20 seconds (39%) of the assessment.

During the *child-parent play* pre-treatment assessment, Alex demonstrated a total of 40 instances of *Non Engagement:* 39 instances of *away from interaction*, and one instance of *tantrum.* Alex demonstrated behaviors of *Non Engagement* for a total of three minutes and 20 seconds (20%) of the pre-treatment *child-parent play* assessment. During the *child-parent play* post treatment assessment, Alex demonstrated a total of 13 instances of *Non Engagement:* 13 instances of *away from interaction*, and no instances of *tantrum.* Alex demonstrated behaviors of *Non Engagement* for a total of one minute and five seconds (6%) of the post treatment *child-parent play* assessment. Figure 13 presents the frequency of *Non Engagement* behaviors during Alex's pre and post *child-parent* assessment.

Child-clinician play assessment. Results of Chris's pre and post treatment *child-clinician play* assessments are presented in Table 6. Chris and his clinician participated in the *child-clinician play* pre-treatment assessment for a total of eight minutes and 15 seconds. They participated in the *child-clinician play* post treatment assessment for a total of 11 minutes and 35 seconds, which was three minutes and 20 seconds longer than the pre-treatment assessment. Figure 14 presents the length of Chris's *child-clinician* pre and post treatment assessments as well as the duration of engagement during the pre and post treatment *child-clinician* assessments.

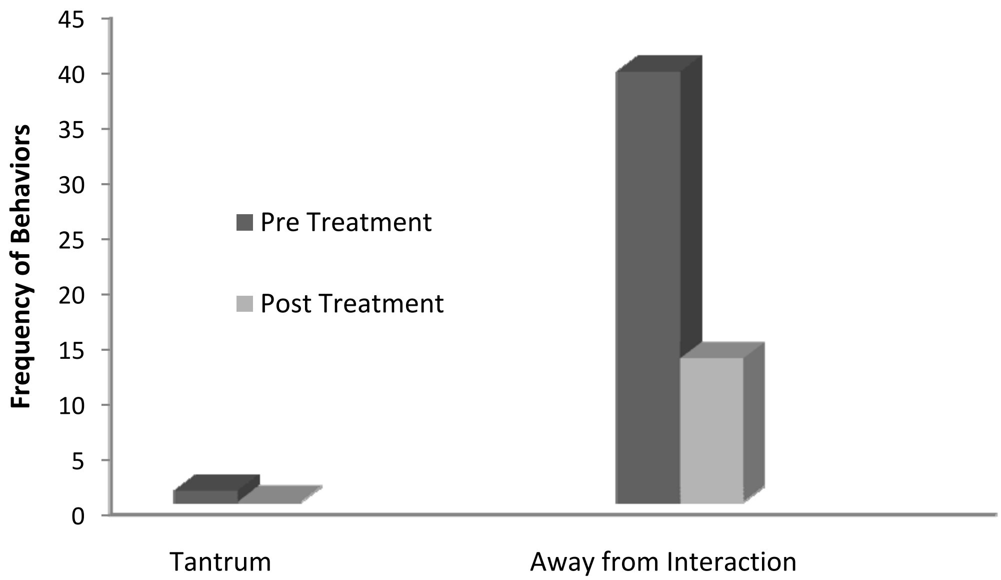

Figure 13. Number of *Non Engagement* behaviors coded for Alex's pre and post *child-parent* assessments.

Table 6

Chris's Results for the Child-Clinician Play Assessment

	Initiating engagement				Responding to engagement				Non Engagement	
	Lang	Affect	Imitation	EC	Lang	Affect	Imitation	EC	Away from Interaction	Tantrum
Pre-Tx	10	1	1	3	10	0	10	2	5	0
Post Tx	20	0	1	9	10	4	1	14	20	3

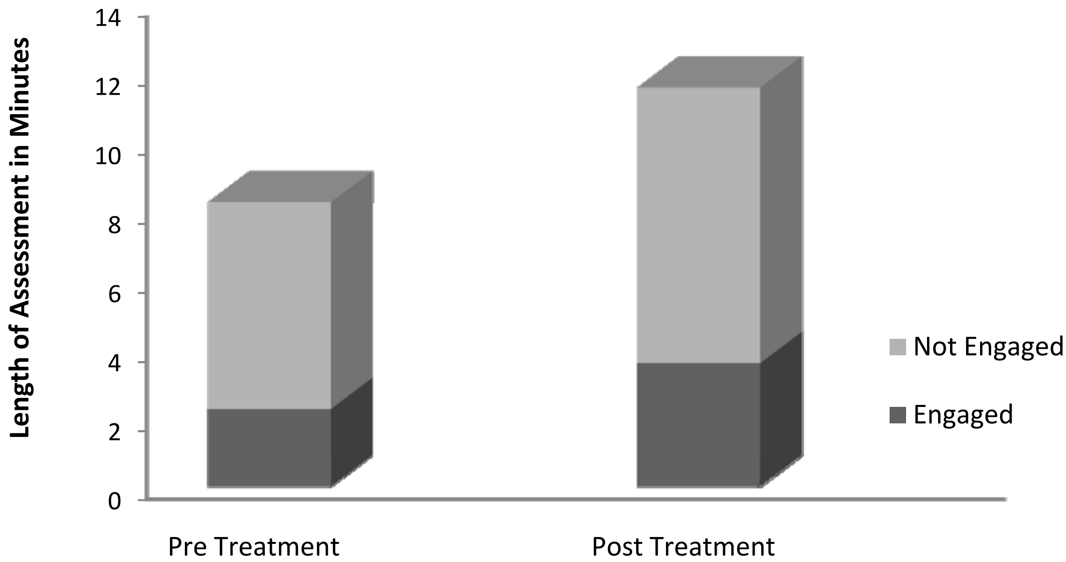

Figure 14. Length of the assessment and length of engagement versus non-engagement in minutes and for Chris's pre and post *child-clinician* assessments.

During the *child-clinician play* pre-treatment assessment, Chris demonstrated a total of 15 instances of *Initiating Engagement:* 10 instances of *language,* one instance of *affect,* one instance of *imitation,* and three instances of *eye contact.* Chris demonstrated behaviors of *Initiating Engagement* for a total of 55 seconds (11%) of the *child-clinician play* pre-treatment assessment. During the *child-clinician play* post treatment assessment, Chris demonstrated a total of 30 instances of *Initiating Engagement:* 20 instances of *language,* no instances of *affect,* one instance of *imitation,* and nine instances of *eye contact.* Chris demonstrated behaviors of *Initiating Engagement* for a total of one minute and 40 seconds (14%) of the *child-clinician* post treatment assessment. Figure 15 presents the frequency of *Initiating Engagement* behaviors during Chris's pre and post *child-clinician* assessment.

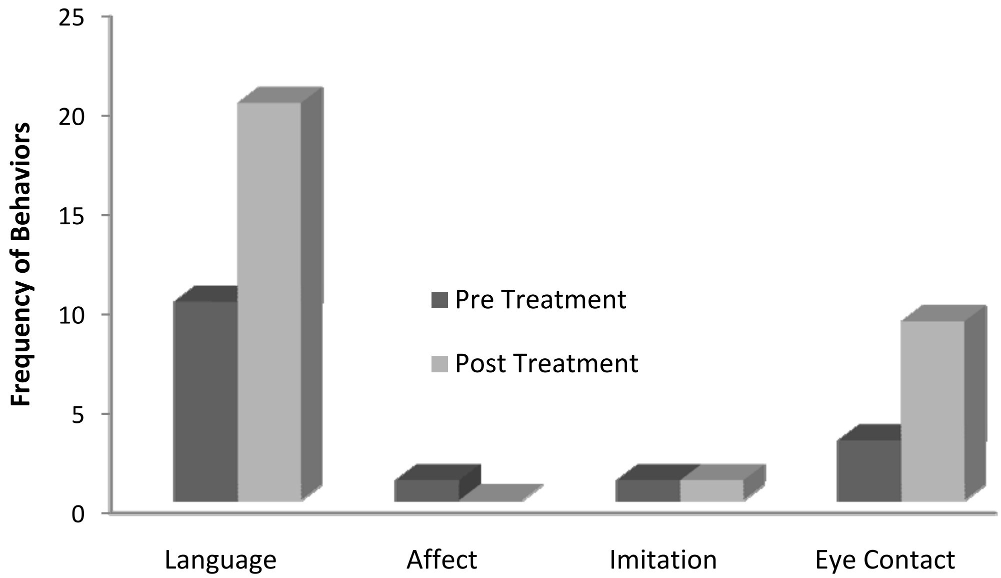

Figure 15. Number of *Initiating Engagement* behaviors coded for Chris's pre and post *child-clinician* assessments.

During the *child-clinician play* pre-treatment assessment, Chris demonstrated a total of 22 instances of *Responding to Engagement:* 10 instances of *language,* no instances of *affect,* 10 instances of *imitation,* and two instances of *eye contact.* Chris demonstrated behaviors of *Responding to Engagement* for a total of one minute and 20 seconds (16%) of the *child-clinician* pre-treatment assessment. During the *child-clinician play* post treatment assessment, Chris demonstrated 29 total instances of *Responding to Engagement:* 10 instances of *language*, four instances of *affect,* one instance of *imitation*, and 14 instances of *eye contact.* Chris demonstrated behaviors of *Responding to Engagement* for a total of one minute and 55 seconds (17%) of the *child-clinician play* post treatment assessment. Figure 16 presents the frequency of *Responding to Engagement* behaviors during Chris's pre and post *child-clinician play* assessment. During the *child-clinician play* post treatment assessment, Chris either initiated or responded to engagement in an activity with his clinician for a total of two minutes and 15 seconds (27%) of the assessment. During the *child-clinician play* post treatment assessment, Chris either initiated or responded to engagement in an activity with his clinician for a total of three minutes and 35 seconds (31%) of the assessment.

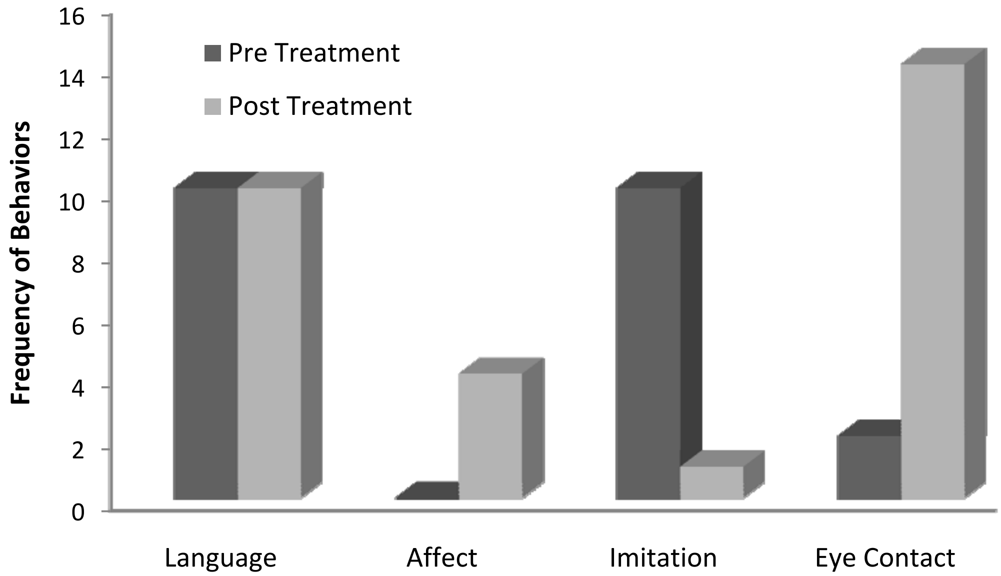

Figure 16. Number of *Responding to Engagement* behaviors coded for Chris's pre and post *child-clinician* assessments.

During the *child-clinician play* pre-treatment assessment, Chris demonstrated a total of five instances of *Non Engagement:* five instances of *away from interaction*, and no instances of *tantrum.* Chris demonstrated behaviors of *Non Engagement* for a total of 25 seconds (5%) of the *child-clinician play* pre-treatment assessment. During the *child-clinician play* post treatment assessment, Chris demonstrated a total of 23 instances of *Non Engagement:* 20 instances of *away from interaction*, and three instances of *tantrum.* Chris demonstrated behaviors of *Non*

Engagement for a total of one minute and 55 seconds (17%) of the *child-clinician play* assessment. Figure 17 presents the frequency of *Non Engagement* behaviors during Chris's pre and post *child-clinician* assessment.

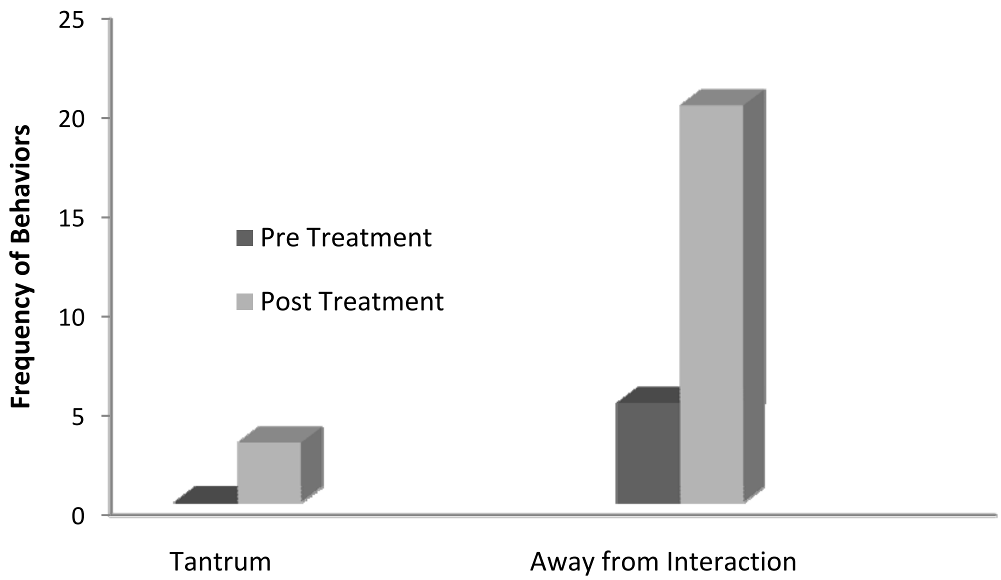

Figure 17. Number of *Non Engagement* behaviors coded for Chris's pre and post *child-clinician* assessments.

Results of Alex's pre and post treatment *child-clinician play* assessments are presented in Table 7. Alex and his clinician participated in the *child-clinician play* pre-treatment assessment for a total of seven minutes and 30 seconds. They participated in the *child-clinician play* post treatment assessment for a total of 21 minutes and 25 seconds, which was 13 minutes and 55 seconds longer than the pre-treatment assessment. Figure 18 presents the length of Alex's *child-clinician* pre and post treatment assessments as well as the duration of engagement during the pre and post treatment *child-clinician* assessments.

Table 7

Alex's Results for the Child-Clinician Play Assessment

	Initiating engagement				Responding to engagement				Non Engagement	
	Lang	Affect	Imitation	EC	Lang	Affect	Imitation	EC	Away from Interaction	Tantrum
Pre-Tx	0	0	0	1	6	1	5	14	14	1
Post Tx	9	0	0	19	39	3	24	68	7	0

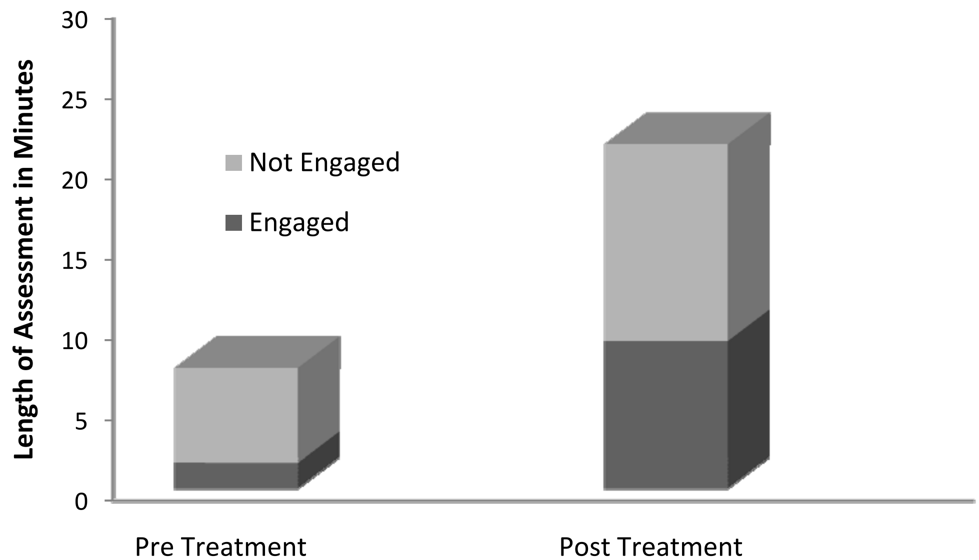

Figure 18. Length of the assessment and length of engagement versus non-engagement in minutes and for Alex's pre and post *child-clinician* assessments.

During the *child-clinician play* pre-treatment assessment, Alex demonstrated one instance of *Initiating Engagement:* no instances of *language*, no instances of *affect*, no instances of *imitation*, and one instance of *eye contact.* Alex demonstrated behaviors of *Initiating Engagement* for a total of 5 seconds (1%) of the *child-clinician play* pre-treatment assessment. During the *child-clinician play* post treatment assessment, Alex demonstrated a total of 28 instances of *Initiating Engagement:* nine instances of *language,* no instances of *affect,* no instances of *imitation,* and 19 instance of *eye contact.* Alex demonstrated behaviors of *Initiating Engagement* for a total of one minute and 45 seconds (8%) of the *child-clinician play* post treatment assessment. Figure 19 presents the frequency of *Initiating Engagement* behaviors during Alex's pre and post *child-clinician* assessment.

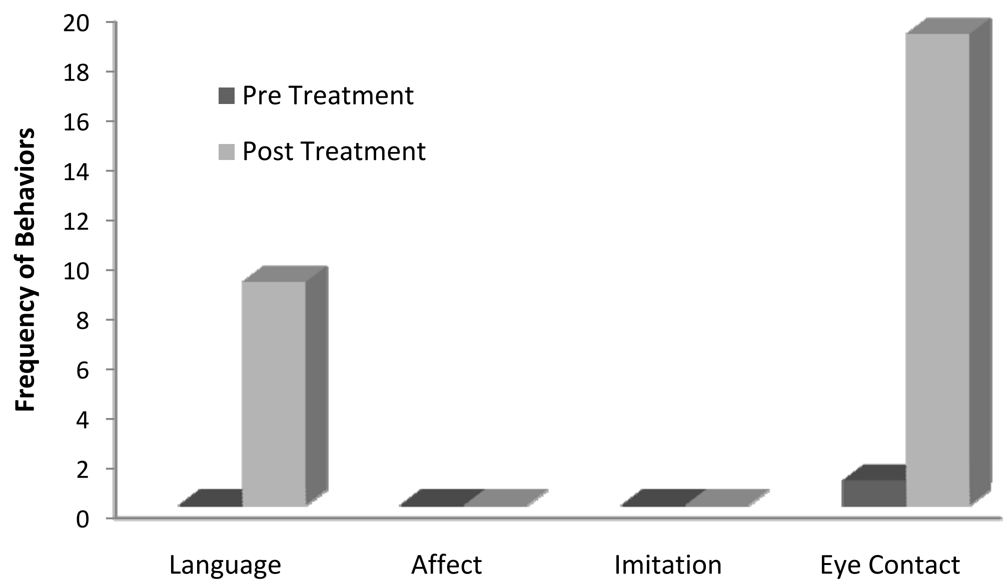

Figure 19. Number of *Initiating Engagement* behaviors coded for Alex's pre and post *child-clinician* assessments.

During the *child-clinician play* pre-treatment assessment, Alex also demonstrated a total of 26 instances of *Responding to Engagement:* six instances of *language,* one instance of *affect,* five instances of *imitation,* and 14 instances of *eye contact.* Alex demonstrated behaviors of *Responding to Engagement* for a total of one minute and 30 seconds (20%) of the *child-clinician play* pre-treatment assessment. During the *child-clinician play* post treatment assessment, Alex demonstrated a total of 134 instances of *Responding to Engagement:* 39 instances of *language,* three instances of *affect*, 24 instances of *imitation*, and 68 instances of *eye contact.* Alex demonstrated behaviors of *Responding to Engagement* for a total of seven minutes and 25 seconds (35%) of the *child-clinician play* post treatment assessment. Figure 20 presents the frequency of *Responding to Engagement* behaviors during Alex's pre and post *child-clinician* assessment. During the *child-clinician play* pre-treatment assessment, Alex either initiated or responded to engagement in an activity with his clinician for a total of one minute and 35 seconds (21%) of the assessment. During the *child-clinician play* post treatment assessment, Alex either initiated or responded to engagement in an activity with his clinician for a total of nine minutes and 10 seconds (43%) of the assessment.

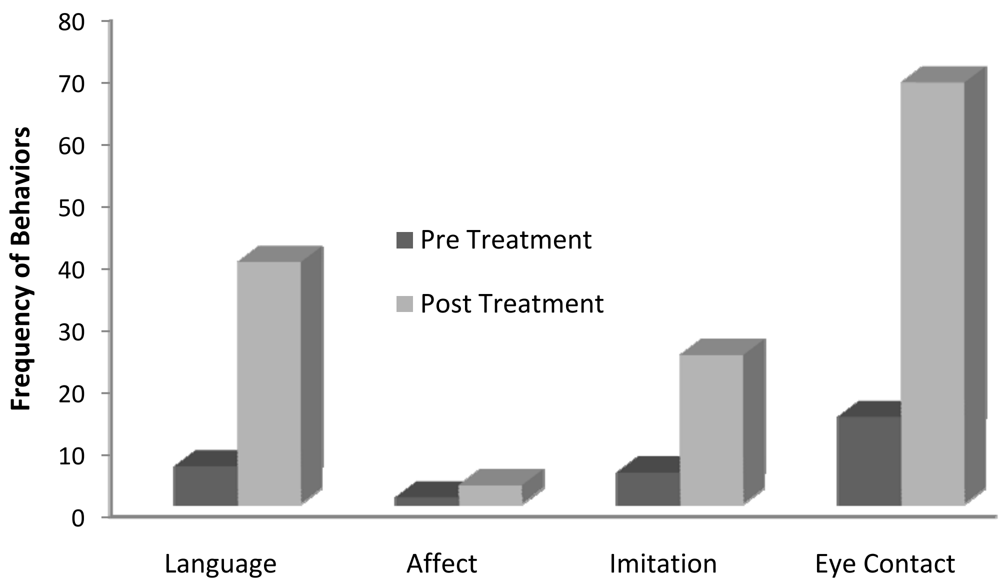

Figure 20. Number of *Responding to Engagement* behaviors coded for Alex's pre and post *child-clinician* assessments.

During the *child-clinician play* pre-treatment assessment, Alex demonstrated a total of 15 instances of *Non Engagement:* 14 instances of *away from interaction*, and one instance of *tantrum.* Alex demonstrated behaviors of *Non Engagement* for a total of one minute and 15 seconds (16%) of the *child-clinician play* pre-treatment assessment. During the *child-clinician play* post treatment assessment, Alex demonstrated a total of seven instances of *Non Engagement:* seven instances of *away from interaction*, and no instances of *tantrum.* Alex demonstrated behaviors of *Non Engagement* for a total of 35 seconds (3%) of the *child-clinician play* post treatment assessment. Figure 21 presents the frequency of *Non Engagement* behaviors during Alex's pre and post *child-clinician* assessment.

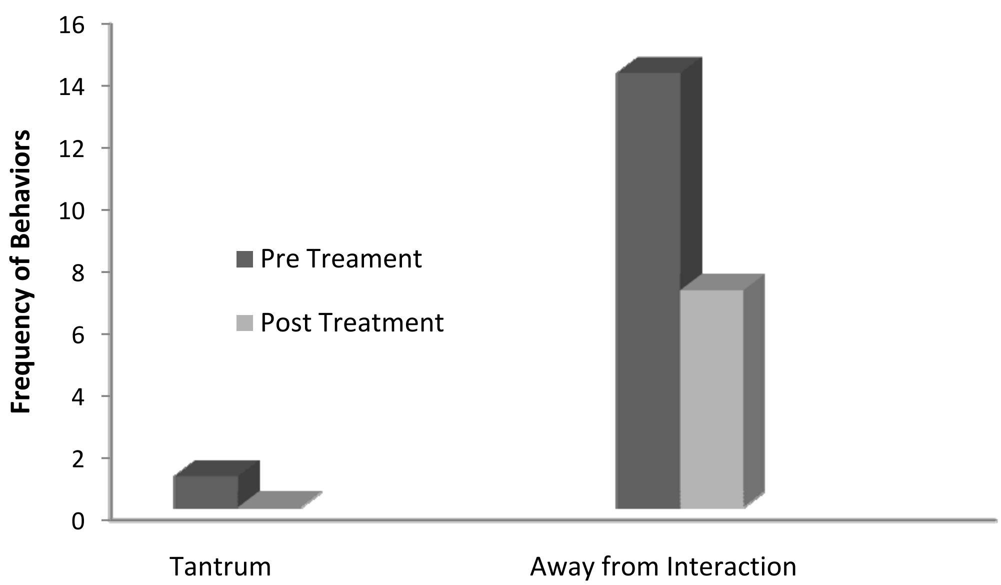

Figure 21. Number of *Non Engagement* behaviors coded for Alex's pre and post *child-clinician* assessments.

Clinical Observations

In addition to the results of the analysis of target behaviors, several clinical observations noted that were not captured by the data analysis system. These behaviors included the participants' acclimation to, and interest in, the robot, observed effects of the interaction with the robot on intervention conducted without the robot, and changes in the participants' restricted interests and repetitive play. These observations are discussed below.

Both Alex and Chris were immediately engaged in and motivated by the robot. Unlike some other studies involving robots in therapy with children with autism, neither Alex nor Chris required a long acclimation period before they were interested in interacting with Troy (Francois et al., 2009; Kozima & Nakagawa, 2006; Kozima et al., 2005; Robins et al., 2005; Robins et al., 2004). Instead, both Alex and Chris were interested in interacting with Troy during the first treatment session in which the robot was introduced, and neither child displayed signs of discomfort, fear, or apprehension. Indeed, during Alex's first treatment session, Alex requested to interact with Troy by handing his clinician a picture of Troy. This was significant for two reasons. First, Alex rarely requested or initiated any activity during a session, including activities that he had demonstrated interest in, such as puzzles or blocks. Second, prior to the study, Alex had not demonstrated understanding that pictures represented objects or individuals. Indeed, this concept had been a therapy goal for Alex for several months and no progress had been observed. Alex continued to request to interact with Troy by handing his clinician a picture of Troy throughout the remainder of the study.

Throughout the study it became apparent that Alex and Chris were highly motivated and interested in the robot. Interacting with Troy seemed to be both Alex's and Chris's favorite session activity, not including activities that involved the children's restricted interests. Both

Alex and Chris often requested to play with Troy throughout the treatment sessions, regardless of whether or not they had already interacted with Troy during that session. If the robot activity was scheduled for the beginning of the session, the children often requested to interact with Troy again later in the session. Likewise, if the robot activity was scheduled for the end of the session, the children often requested to play with Troy before the scheduled time. For example, Chris would often look at his therapy picture schedule and say, "Troy please," thus requesting that he and his clinician play with Troy. Likewise, at the beginning of every session, Alex always stood at the door to the therapy room where Troy was located and requested that the clinician open the door by looking at the clinician and producing a verbal approximation to the word *open*.

Interacting with Troy seemed to have a positive effect on other interactions that occurred during the treatment sessions. After interacting with Troy, both Chris and Alex displayed continued enthusiasm during other activities throughout the remainder of the session. They seemed more compliant and demonstrated more frequent behaviors of *Initiating Engagement* and *Responding to Engagement*. For example, Chris enjoyed initiating social games with Troy, such as taking turns making different facial expressions to express emotion. Chris initiated the interaction by frowning and saying, "sad." Chris's clinician then changed Troy's face to a sad face. The clinician then responded with affect by saying, "sad," and producing crying-like sounds and facial expressions. Chris was highly engaged during these exchanges and eventually initiated these exchanges with his clinician during the regular part of his therapy session. In addition, both children willingly engaged in activities with Troy that they had not previously engaged in. For example, neither Alex nor Chris pushed a car to their clinician during the pre-treatment assessments. However, both children willingly pushed a car to the clinician while interacting with Troy, and they continued to participate in these reciprocal activities when Troy was not present.

Interacting with Troy also seemed to have a positive impact on interactions that occurred outside of the treatment sessions. For example, both Alex and Chris enjoyed initiating social greetings with Troy by waving *hello* and *good-bye*. These social greetings then generalized to other settings outside of the treatment sessions. Alex began waving good-bye to his clinician when the session was finished, and occasionally waved to unfamiliar individuals who greeted him. Chris also began regularly greeting the clinicians before and after the treatment sessions, and on one occasion, spontaneously greeted the assisting clinician in the parking lot prior to a session.

Finally, interacting with Troy seemed to have a positive effect on the participants' restricted interests and repetitive play. Prior to the study, Alex repetitively spun objects and toys, while Chris displayed restrictive interest in playing with LEGO® men. While interacting with Troy, instead of participating in solitary repetitive routines, the children initiated activities of social engagement with Troy using objects that were previously constrained to repetitive routines. For example, Chris occasionally shared his LEGO® man with Troy during an interaction by showing Troy his LEGO® man, or allowing the LEGO® man to be pushed in a car to Troy. Demonstrating a desire to share a LEGO® man with Troy was significant because Chris had previously refused to share or engage in an interaction with another person while a LEGO® man was available. Likewise, during interactions with Troy, Alex rarely twirled toys available in the therapy room. Rather, Alex played with toys appropriately in order to engage Troy in an interaction. Again, this was clinically significant because Alex rarely played appropriately with toys. Indeed, appropriate play was one of Alex's treatment goals that had seen little progress over several months prior to this study.

Discussion

The purpose of this study was to investigate the effect of a low-dose treatment using a humanoid robot on social engagement in two children, Alex and Chris, who were identified with ASD. Two assessments were conducted pre- and post treatment with the humanoid robot. Results were analyzed for both frequency and duration of behaviors of *Initiating Engagement*, *Responding to Engagement*, and *Non Engagement*. A summary of the results, possible explanations for the results, and suggestions for future research are discussed below.

Summary and Evaluation of Results

Results showed that Chris demonstrated a decrease of all target behaviors in the child-parent post treatment assessment with the exception of eye contact in the *Responding to Engagement* category, which increased in frequency during the post treatment child-parent assessment. During the child-clinician post treatment assessment, Chris demonstrated an increase of language and eye contact in the *Initiating Engagement* category, and an increase of affect and eye contact in the *Responding to Engagement* category. Chris demonstrated a decrease of affect in the *Initiating Engagement* category and a decrease of imitation in the *Responding to Engagement* category during the child-clinician post treatment assessment.

Alex, on the other hand, showed a dramatic increase in frequency and duration of behaviors in the categories of *Initiating Engagement* and *Responding to Engagement* during both post treatment assessments. Alex also showed a marked decrease in frequency and duration of behaviors of *Non Engagement* during both post treatment assessments. Some possible explanations for these results are discussed below.

Both children displayed an increased use of eye contact during both post treatment assessments. One reason for this may be that, by looking at Troy's face, the children may have learned that making eye contact with others during an interaction was engaging. Troy's face was patterned after a culturally typical human face in that he had two blue eyes, two brown eye brows, a pink nose, and a red mouth. However, unlike typical human facial features, Troy's facial features were simple, geometric, and predictable. Troy only expressed three distinct facial expressions (neutral, happy, and sad) and Troy produced those facial expressions in exactly the same way every time. Thus, the children were able to observe Troy's face and eyes without being distracted by complex facial features or expressions. The children also observed their clinicians making eye contact with Troy during engaging interactions, which may have helped the children learn how to make appropriate eye contact with a communication partner. During the robot treatment sessions, the children learned to make eye contact with Troy, and eventually generalized that skill to their clinicians during the robot sessions. Eventually, this skill generalized to the regular treatment sessions, and was subsequently observed with other communication partners outside of the treatment room.

Both children also showed an increased use of affect during both post treatment assessments. This may be because both children were very motivated by and engaged in interactions with Troy. The children may have experienced affect because they were so motivated by the interaction. Perhaps because the environment was simple, repetitive, and motivating, both children may have made the connection between experiencing an emotion and appropriately displaying that emotion during an interaction. Both children observed Troy and their clinicians repeatedly expressing affect in a motivating yet controlled situation. Soon, both children responded with affect as well.

Although Alex showed marked improvement, Chris showed a decrease in most engagement behaviors in the post treatment assessments. There may be several explanations for the different results. First, when considering the *child-parent* assessment, each child's parent interacted with him differently. Chris's father interacted with him in a different manner than did the clinician during treatment. Instead of engaging Chris in play with the provided toys, Chris's father engaged Chris by asking him to name the provided toys. In contrast, because Alex's mother was present during all of his treatment sessions, she observed how Alex's clinician interacted with him, and she modeled her interaction after the clinician. Thus, Alex's mother interacted with Alex in much the same manner that Alex's clinician interacted with him during treatment. The clinician's interaction style during treatment was geared to elicit and support the behaviors under study. Chris may not have produced those behaviors with his father because his father's interactions post treatment did not elicit them as effectively.

Another possible reason for the difference in results may involve Troy's movement capabilities. Troy was a fairly simple robot and produced a limited number of movements, which required the treatment activities to be simple in nature. Alex was a preschooler at the time of the study, and he was interested in the simple activities that Troy performed. Chris, however, was eight at the time of the study, and he may have preferred more complex and mature activities than Troy was able to execute. Perhaps if Troy had been capable of participating in more complex activities with more movement, Chris may have been motivated to generalize what he experienced with Troy outside the treatment room. It was the case, however, that Chris was consistently motivated to interact with Troy.

Another possible reason for the difference in results may involve what each child appeared to learn from Troy. Before the robot treatment sessions were implemented, Alex did not imitate his mother's or his clinician's language or actions. Once Troy was introduced, however, Alex began first to imitate Troy's words and actions and eventually imitated words and actions of his clinician and his mother. These interactions were very engaging for him and he began to learn new words very quickly. In contrast, Chris had already learned how to imitate before Troy was implemented in therapy. Indeed, imitating his clinician's carrier phrases was largely how Chris communicated his basic wants and needs.

Finally, differences in the two boys' response to treatment may have been due to each child's behavioral tendencies and patterns. Chris's behavior was highly volatile. He responded differently from session to session depending on a myriad of factors such as his health, medication, stress level at home and school, etc. It was not uncommon for Chris's family member to note, "Chris is having a bad day," when Chris came to treatment. On these days, Chris's behavior was often problematic, and he did not respond well to intervention activities. In contrast, Alex's behaviors were fairly consistent throughout the study. Alex regularly showed interest in the same activities throughout the study and his behaviors did not seem to be as affected by as many outside factors. It may have been more illustrative to gather pre and post treatment assessment data over several days rather than just two. That way, the data may have contained a more representative sample of Chris's overall behavior patterns.

Although the analysis system showed a decrease of target behaviors in Chris, clinical observations over several weeks showed positive behaviors not observed previously. For example, Chris was highly motivated by the robot and frequently requested to play with Troy during treatment sessions. Prior to the study, Chris did not regularly request any activity other than playing with LEGOS®. Chris also began to greet others outside of the treatment room. Although greeting others had been a treatment goal during the year prior to the study, little or no progress had been made. Finally, Chris demonstrated a willingness to share his restricted interests with Troy. Prior to the study, Chris did not demonstrate a willingness to share his restricted interests with any other communication partner.

Recommendations for Future Research

Future research should expand and improve the methodology used in this study to determine whether or not the use of a humanoid robot has a significant effect on social engagement in children with ASD. First, more single subject studies with multiple baselines are needed. The behaviors of many children with ASD may be affected by extraneous factors. Thus, a single-subject study with multiple baselines would help reduce the effect of extraneous factors on the data gathered.

Second, a larger sample size is required to determine whether this approach is appropriate for children with ASD. Even though a detailed description of each child was provided in this study, the sample size was limited to two children. A larger sample size must be obtained in order to determine if the use of a humanoid robot is an appropriate and efficient form of treatment for children with ASD.

Third, future research should include parental involvement and education throughout the study for each of the participants involved in order to determine if the use of a humanoid robot in therapy with children with ASD would improve their social interactions with family members. Even if the use of a robot does improve the social engagement behaviors of a child with ASD, if the parents are not educated on the type of interaction used, those behaviors may not generalize to the home.

Finally, future research should involve robots that are specifically designed to appeal to the children with varying levels of maturity. It may be that different design may be more effective for children of different ages and levels of functioning. Future research should determine if older children with ASD are more engaged with the robot if it is more complex and capable of more mature movement.

Conclusion

Results showed that Chris demonstrated a decrease of all target behaviors in the *child-parent* post treatment assessment with the exception of *eye contact* in the *Responding to Engagement* category, which increased in frequency during the post treatment *child-parent* assessment. During the *child-clinician* post treatment assessment, Chris demonstrated an increase of *language* and *eye contact* in the *Initiating Engagement* category, and an increase of *affect* and *eye contact* in the *Responding to Engagement* category. Chris demonstrated a decrease of *affect* in the *Initiating Engagement* category and a decrease of *imitation* in the *Responding to Engagement* category during the *child-clinician* post treatment assessment. Alex, on the other hand, showed a dramatic increase in frequency and duration of behaviors in the categories of *Initiating Engagement* and *Responding to Engagement* during both post treatment assessments. Alex also showed a drastic decrease in frequency and duration of behaviors of *Non Engagement* during both post treatment assessments. Clinical observation also indicated that both children may have benefited from use of a humanoid robot during treatment. Indeed, both children demonstrated clinically relevant changes in behaviors not targeted by the data analysis system.

These findings are reminiscent of previous studies which suggest that children with ASD may benefit from the use of a humanoid robot in intervention. This study suggests that a low-dose treatment that emphasizes interaction involving the robot as well as other human conversational partners may be effective for some children. Continued research is warranted to determine which children may benefit from intervention using a robot, and what types of intervention are most beneficial.

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Appendix A

Alex's Individualized Education Plan Goals from his Special Education Preschool for the 2009-2010 School Year

Goal	Results
Alex will point to at least 5/11 basic colors (red, yellow, blue, green, orange) when presented in random order for 3 out of 4 consecutive data probes.	11/20/09 "Alex is beginning to understand the cue 'Touch - ___.' When he's attentive and happy, he can do this well with no distracters. He hasn't figured out the concept of color yet, so when a distracter is present, he chooses randomly." 3/5/10 "This is not Alex's favorite task (highly structured trials), but he is willing to try for a few minutes. He can do the 'touch ____' very consistently now but he is still not terribly consistent with a distracter. He does not name any colors consistently, but he does repeat most of them."
Alex will name at least 4/6 basic shapes (circle, square, triangle, rectangle, diamond, oval) when presented in random order for 3 out of 4 consecutive data probes.	11/20/09 "Similar to the colors above, he can do quite well without a distracter. We will focus more on colors than shapes for awhile so as not to confuse him too much." 3/5/10 "Still similar to above. However, he's taking more interest now and he loves to match shapes. He's much more efficient at matching shapes than colors and he will repeat the names of shapes sometimes."

Alex will identify (say or sign) 10 pair of objects as the "same" or "different" with 80% accuracy for 3 out of 4 consecutive data probes.	11/20/09 "This goal is very much at the exposure stage. He does not understand the concept of same/different at all yet, but he's willing to participate and let us help him sign 'same.' We'll keep working on it." 3/5/10 "He's starting to get the hang of it a little and will put more attention into the task. He has the physical concept of matching things that are the same fairly well with some materials, such as puzzles and file folder games, but I don't think he understands the vocabulary yet."
Alex will initiate and maintain appropriate, interactive play with a peer for 10 minutes during play/socialization time for 3 out of 4 consecutive data probes.	11/20/09 "Right now our focus is on helping Alex feel comfortable and happy at preschool. We are thrilled when he chooses to play and engage in the activities we have going on. Most of his play is solitary at this time, but he is beginning to enter on-going play with peers and stay for a minute or two before moving on to something else." 3/5/310 "Alex is making great progress with social skills right now. He is starting to be able to stay in large and small group settings for longer periods of time and tolerate peers sitting and playing closer to him. He still plays by himself much of the time or walks away when too many people are playing close to him. However, he is playing with several toys appropriately and for longer periods of time (3-6 minutes or more) before moving on to something else. He's making eye contact a lot more with adults and peers and smiling at them. It's a significant first step. He's not shy at all about walking up and joining other kids' play, but he doesn't stay long (30 sec - 2 min). He doesn't ask to play, but he's starting to just do what they're doing or gives them a toy. Sometimes he will play for 2-3 minutes with a peer, but it usually only happens once or twice during a day with the rest being primarily solitary or adult-interaction."

Alex will attend to/participate in a structured task of the teacher's choice for 5 minutes (similar to non-disabled peers) with two or fewer verbal prompts for 3 out of 4 consecutive data probes.	11/20109 "This varies significantly based on how he is feeling. When he is happy and calm, he can participate for up to 10 minutes in both tasks of his choice and those the teacher directs. However, on other days, he cries much of the time and hardly participates at all in some of the activities. He tends to attend better in the first half of the day." 3/5/10 "He has progressed significantly in this area! We're up to full class sessions now! He hardly ever cries anymore and he participates in almost all of our planned activities, with minimal to moderate assistance."
Alex will participate willingly, appropriately, and independently in at least 4 out of 6 of the following classroom routines: (1) entry, (2) circle time, (3) play time, (4) snack, (5) small groups, and (6) good-bye, for 3 out of 4 consecutive data probes.	11/20109 "This is coming along well. For the first few weeks, he needed a one-on-one aide constantly. Now, he has her about 60~70% of the time, sometimes less. When he's not crying, he participates in everything we're doing, often vocalizing and/or imitating gross motor movements." 3/5/10 "Huge improvement here!! He understands the routine so much better. He still needs one-on-one assistance about 30% of the day (down from 90%). He needs some additional re-direction to stay on task, but he's not actively trying to escape, he just sort of loses interest and wanders off. .. We're working on helping him expand his interests into more areas."

Alex will improve receptive language by (1) demonstrating awareness of safety words (stop, stay here, etc) and by complying with the instruction; (2) by following 1-step commands; and (3) by demonstrate understanding of basic concepts (put in, take out, up, down, etc) by pointing to the appropriate picture or performing the appropriate action.	No date provided. "Alex's performance on this goal is highly variable, depending on his mood. When he is interested and happy, he can do this goal with at least 80% accuracy."
Alex will improve expressive language by sing hand signals (ASL) and/or verbal words to make requests with the support from the speech therapist (using hand-over-hand, repetition, etc).	No date provided. "With support, Alex performs very well on this goal."
Alex will participate in health enhancing levels of physical activity by (1) initiating six exercises independently, (2) complete four exercises of choice on three separate trials, (3) participating during loco motion phase of class and showing improvement on three forms of movement for a minimum of 10 feet each and starting and stopping on associated command, and (4) demonstrating the ability to work with the class and take turns when directed independently.	No date provided. "Just the last couple times we have done PE, Alex has progressed by leaps and bounds. It started about 5 weeks ago when he was staying with the group during exercises and not wandering off. Each week we have seen him do more and more of our activities. We have been doing movement with music and Alex has been watching and following his peers quite well."
Alex will demonstrate improved fine motor, self help, and visual perceptual skills by (1) performing a variety of arm/hand strengthening exercises, such as removing small objects from theraputty, placing clothes pins on the edge of a container, pulling apart a pop-tube, squeezing balls, etc, for five minutes; (2) performing various fine motor activities, such as picking up small objects, string beading, lacing, clothing fasteners, etc, for at least five minutes.	No date provided. "Behavior has interfered with progress toward goals."

Appendix B

Alex's Individualized Education Plan Assessment Results from his Special Education Preschool for the 2009-2010 School Year

Objective	Number of Items	September Assessment		May Assessment		Percent Change September-May
General Concepts	29	+ = 0	0%	+ = 1	3%	3%
		E+ = 0	0%	E+ = 2	7%	7%
		E = 4	14%	E = 3	10%	-3%
		E- = 6	21%	E- = 10	34%	14%
		- = 19	66%	- = 13	45%	-21%
Math Concepts	28	+ = 0	0%	+ = 0	0%	0%
		E+ = 0	0%	E+ = 0	0%	0%
		E = 0	0%	E = 0	0%	0%
		E- = 2	7%	E- = 5	18%	11%
		- = 26	93%	- = 23	82%	-11%
Speech and Language	34	+ = 0	0%	+ = 0	0%	0%
		E+ = 0	0%	E+ = 0	0%	0%
		E = 4	14%	E = 10	29%	18%
		E- = 8	24%	E- = 6	18%	-6%
		- = 22	65%	- = 18	53%	-12%
Attention and Memory	22	+ = 1	5%	+ = 2	9%	5%
		E+ = 1	5%	E+ = 1	5%	0%
		E = 3	14%	E = 6	27%	14%
		E- = 5	23%	E- = 6	27%	5%
		- = 12	55%	- = 7	32%	-23%
Gross Motor	31	+ = 2	6%	+ = 4	13%	6%
		E+ = 4	13%	E+ = 6	19%	6%
		E = 4	13%	E = 8	26%	13%
		E- = 11	35%	E- = 10	32%	-3%
		- = 10	32%	- = 3	10%	-23%
Fine Motor	33	+ = 1	3%	+ = 4	13%	0%
		E+ = 0	0%	E+ = 6	19%	9%
		E = 3	9%	E = 8	26%	9%
		E- = 7	21%	E- = 10	32%	6%
		- = 22	67%	- = 3	10%	-24%

Self Concept and Self Help	28	+ = 0	0%	+ = 0	0%	0%
		E+ = 1	4%	E+ = 5	18%	14%
		E = 5	18%	E = 7	25%	7%
		E- = 8	29%	E- = 8	29%	0%
		- = 14	50%	- = 8	29%	-21%
Social Play	31	+ = 0	0%	+ = 1	3%	3%
		E+ = 0	0%	E+ = 3	10%	10%
		E = 4	13%	E = 15	48%	35%
		E- = 13	42%	E- = 4	13%	-29%
		- = 14	45%	- = 8	26%	-19%
Reasoning and Responsibility	27	+ = 0	0%	+ = 0	0%	0%
		E+ = 0	0%	E+ = 1	4%	4%
		E = 4	15%	E = 6	22%	7%
		E- = 3	11%	E- = 6	22%	11%
		- = 20	74%	- = 14	52%	-22%
Literacy Foundations	29	+ = 0	0%	+ = 0	0%	0%
		E+ = 0	0%	E+ = 2	7%	7%
		E = 0	0%	E = 2	7%	7%
		E- = 1	3%	E- = 5	17%	14%
		- = 28	97%	- = 20	69%	-28%
Overall Assessment	292	+ = 4	1%	+ = 9	3%	2%
		E+ = 6	2%	E+ = 23	8%	6%
		E = 31	11%	E = 63	22%	11%
		E- = 64	22%	E- = 69	24%	2%
		- = 187	64%	- = 128	44%	-20%

Note. A score of – means that the objective is absent while a score of + means the objective is mastered. A score of *E*- means that the objective is present but rare, a score of *E* means the objective is emerging and seen occasionally, and a score of *E*+ means that the objective is emerging and seen frequently. Adapted from “TK Assessment Results” located in Alex’s IEP.

Appendix C

Alex's Speech and Language Treatment Goals from the Brigham Young University Speech and Language Clinic for Fall Semester 2009

1. Alex will build onto his play skills by attending to an interactive activity for 7-9 minutes with moderate support.
2. Alex will attend to an activity while sitting on a chair at a table for 8-10 minutes
3. Alex will expand his symbolic play skills by demonstrating the ability to feed a doll with moderate support.
4. Alex will demonstrate joint attention by taking 5 turns during a 3 minute activity with maximal support.
5. Alex will demonstrate understanding of the following commands: wait, sit down, hold hand, and clean up with moderate support.
6. Alex will verbalize the names or sounds of the following letters: H, L, F, Y, and C.
7. Alex will demonstrate appropriate usage of "more" in 6/8 opportunities with maximum support.
8. Alex will demonstrate the ability to point distally with moderate support.

Appendix D

Alex's Speech and Language Treatment Goals from the Brigham Young University Speech and Language Clinic for Fall Semester 2009

1. Alex will attend to an interactive activity for 7-10 minutes with moderate support from the clinician.
2. Alex will attend to a table activity for 8-10 minutes with moderate support from the clinician.
3. Alex will participate in appropriate symbolic play (either self or with a toy) during a 50-minute session over two consecutive sessions with moderate support from the clinician.
4. Alex will demonstrate joint attention by making eye contact 10 times in a 5 minute activity over two consecutive sessions with moderate support from the clinician.
5. Alex will demonstrate joint attention by initiating an activity three times during a 5 minute activity, with moderate support from the clinician.
6. Alex will demonstrate joint attention by taking 10 turns during a 5 minute activity with moderate support.

Appendix E

Chris's Individualized Education Plan Goals from his Special Education Classroom for the 2009-2010 School Year

Goal	Results
Chris will write his name, address, or phone number when given a verbal or written cue with 90% accuracy for four out of five consecutive trials.	2/2/2009 "Chris can trace a circle, square, triangle and line. He is able to write *Chris* but has difficulty keeping the letters a consistent size. Chris can trace uppercase and lowercase letters within one half inch of the line." 1/21/2010 "Based on informal classroom observations and assessments done on 1/21/2010, Chris can trace a circle, square, triangle and line. When told a number between 1 and 10, Chris can write the number correctly in 4/5 trials. He writes letters uppercase and lowercase with minimal verbal prompting. Chris is able to write his first name without a model in 4/5 trials, but needs a model to correctly write his last name. Based on his current writing skills, his needs would not be met in a general education setting."
Chris will use touch points to add one-digit by one-digit numbers 1-9 when given 10 different problems, with 80% accuracy for four out of five consecutive trials.	2/2/2009 "Chris can verbally identify the numbers through the thousands. He still has some difficulty with one-to-one correspondence." 1/20/2010 "According to classroom observations and assessments done on 1/20/2010, Chris can verbally identify the numbers through the thousands. Chris can independently rote count to 20, with prompting he can rote count to 35. Chris is able to count up to 10 objects and match them with their corresponding number. Chris correctly places touch points on numbers 1-5. He is able to use touch points to complete addition problems 1+1, 1+2, 1+3, 1+4, 1+5 and 2+2. He still needs prompting to correctly complete addition problems using numbers 2-5. Based on his current math skills, Chris's needs would not be met in a general education setting."

Chris will read 75 new sight words when given a list of words and the verbal prompt to "read" with 90% accuracy for four out of five consecutive trials.	2/2/2009 "Chris can verbally identify all of the letters. He enjoys naming letters as he sees them. Chris can also verbally identify colors and shapes. Chris is able to read 23 sight words including: *Mom, Dad, Chris, yellow, blue, green, red, white, black, orange, purple, brown, pink, dog, cat, mouse, lion, pig, bird, monkey, horse, cow,* and *car*." 1/20/2010 "According to classroom observations and assessments done on 1/20/2010, Chris can verbally identify colors and shapes. Chris enjoys reading words that he recognizes. He also enjoys reading books with words that he recognizes. Chris is able to read 43 sight words including: *Mom, Dad, Chris, yellow, blue, green, red, white, black, orange, purple, brown, pink, dog, cat, mouse, lion, pig, chicken, fish, bird, monkey, horse, cow, car, little, airplane, see, the, put, a, girl, ball, I, box, and, with, in, boy, to, candy, go* and *tree*. Chris's current reading skills do not allow him to access the 2nd grade general curriculum."
Chris will independently use scissors to cut within ¼ inch of a line when given a simple picture, with 80% accuracy for four out of five consecutive trials.	2/2/2009 "Chris is able to cut with scissors but still needs help holding the paper correctly. He is able to string 5+ beads and stack 5+ blocks." 1/27/2010 "Chris is able to cut with scissors but still needs help holding the paper correctly. He is able to string 5+ beads and stack 5+ blocks."
Chris will verbally express his wants and needs within his academic setting using 2-3 word phrases.	2/2/2009 "Chris is able to follow simple one-step directions, such as *sit down, come back*, etc." 1/26/10 "On an informal observation during speech group on 1-26-10, Chris was able to respond verbally when presented with choices after prompts from his classroom teacher. Chris is able to use verbal communication when prompted. Chris is able to follow simple directions. Expressive communication continues to be difficult for him. He is unable to effectively express his wants and needs within his academic setting. Due to language delays, Chris will continue to receive speech therapy services to help him communicate more effectively within his academic setting."

Chris will produce CVC targets (single syllable words) after visual cue is given on three consecutive sessions.	2/2/2009 “Chris attempts to imitate most words. He will say *please* independently, but needs prompting to use full sentences.” 1/27/2010 “Chris attempts to imitate most words. He will say "please" independently but needs prompting to use full sentences.”
Chris will participate in every activity during an APE class requiring fewer than five total prompts to stay on task or follow directions.	2/2/2009 “Chris participates in activities with some prompting. He loves running back and forth, but is hesitant to participate in other activities. He usually does not do any of the warm-up activities and he is reluctant to play with balls.” 1/27/2010 “Chris attends my APE class with his class one time per week for 30 minutes. We do stretching, muscle building exercises, and sports skills. Chris needs help during stretching. If he is not prompted he will sit there and not do anything. He loves the running part of our class. He shows no interest in balls so it can be a struggle during the skill sessions. He can be cooperative and, if prompted, will usually participate. There are some days when he is extremely tired and he has fallen asleep in my class, but those instances are decreasing in frequency. We will continue working on sports skills and helping Chris cooperate and participate during APE.”

Appendix F

Chris's Speech and Language Treatment Goals from the Brigham Young University Speech and Language Clinic for Spring Semester 2009

1. Chris will make appropriate eye contact to convey his communicative intent when commenting, requesting, or attending, 3/5 opportunities within a 50-minute session.
2. Chris will participate in constructive play during a 50-minute session.
3. Chris will participate in reciprocal play as demonstrated by him following his clinician's model 3-5 opportunities during one structured activity.
4. Chris will use 3-word phrases to communicate his preference between 2 choices, 3/5 opportunities within one structured activity.
5. Chris will make 3-5 appropriate comments while reading a book/ or during one structured activity within a 50-minute session.

Appendix G

Chris's Speech and Language Treatment Goals from the Brigham Young University Speech and Language Clinic for Winter Semester 2010

1. Chris will make appropriate eye contact 12 times to convey his communicative intent when commenting, requesting, or attending, during a 50 minute session.
2. Chris will participate in reciprocal play as demonstrated by him following his clinician's model on 7 occasions during one structured activity.
3. Chris will use 3-word phrases to communicate wants and needs 15 times during structured activities with moderate support from his clinician.
4. Chris will make 3-5 appropriate comments while reading a book/or during one structured activity within a 50-minute session.

Appendix H

Robot Treatment Protocol

General Principles

1. All exchanges involve shared affect
   - Clinician responds to successful action
   - Robot responds to successful action
   - Clinician responds to unsuccessful action
   - Robot responds to unsuccessful action
2. Hand-over-hand techniques were used as needed to help child perform action.
3. Clinician and Robot will not react with negative emotion to child failure. Instead, clinician will offer encouragement, such as "Almost," or "Just about!"
4. Sequences that involve failure had a "teaching" component where the individual who failed had a chance to make in right.
5. Sequences were performed in quick succession to encourage extended exchanges.
6. Activities were varied according to the child's interest.
7. Robot segments were performed for periods of approximately 10 minutes toward the beginning, middle, and end of the treatment sessions. Times were varied systematically.

Sequence Type		Example
Successful Sequences		
Clinician Initiated	1. Clinician performs action 2. Robot performs action 3. Child performs action	1. Clinician pushes car to Troy 2. Troy pushes car to Alex 3. Alex pushes car to clinician
	1. Clinician performs action 2. Child performs action 3. Robot performs action	1. Clinician sings *Popcorn Popping on the Apricot Tree* 2. Chris sings *Popcorn Popping on the Apricot Tree* 3. Troy sings *Popcorn Popping on the Apricot Tree*

Robot Initiated	1. Robot performs action 2. Clinician performs action 3. Child performs action	1. Troy pushes a ball to clinician 2. Clinician pushes a ball to Alex 3. Alex pushes a ball to Troy
	1. Robot performs action 2. Child performs action 3. Clinician performs action	1. Troy pushes a ball to Chris 2. Chris pushes a ball to the clinician 3. Clinician pushes a ball to Troy
Child Initiated	1. Child performs action 2. Robot performs action 3. Clinician performs action	1. Chris makes a sad face 2. Troy makes a sad face 3. Clinician makes a sad face
	1. Child performs action 2. Clinician performs action 3. Robot performs action	1. Alex waves hello 2. Clinician waves hello 3. Troy waves hello
Unsuccessful Sequences		
Clinician Unsuccessful	1. Robot performs action 2. Clinician attempts action – fails 3. Robot demonstrates action for clinician 4. Clinician re-attempts action again - succeeds 5. Child performs action	1. Troy pushes a car to the clinician 2. Clinician attempts to push the car and fails 3. Troy demonstrates correct way to push the car and pushes the car to the clinician 4. Clinician successfully pushes the car to Alex 5. Alex pushes the car to Troy
Robot Unsuccessful	1. Clinician performs action 2. Robot attempts action – fails 3. Clinician demonstrates action for robot 4. Robot re-attempts action - succeeds 5. Child performs action	1. Clinician waves hello to Troy 2. Troy does not wave hello 3. Clinician demonstrates correct way to wave hello 4. Troy successfully waves hello to Chris 5. Chris waves hello to Troy