The Effect of a Treatment Program Utilizing a Humanoid Robot on Social Engagement of Two Children with Autism Spectrum Disorder

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The Effect of a Treatment Program Utilizing a Humanoid Robot on the Social Engagement of

Two Children with Autism Spectrum Disorder

Margaret Hansen

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

The Effect of a Treatment Program Utilizing a Humanoid Robot on the Social Engagement of Two Children with Autism Spectrum Disorder

Margaret Hansen
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The purpose of this study was to evaluate the use of a robot (Troy) in a low-dose treatment protocol for two children with Autism Spectrum disorder. The efficacy of intervention was measured by comparing social engagement in two contexts: interactions with two adults and interaction with an unfamiliar adult. During the treatment, a robot was included in pseudo-triadic interactions with the clinician and the child. The robot was programmed to perform simple actions that imitated the actions of the clinician in an effort to engage the child. These pseudo-triadic interactions were incorporated into intervention over the course of a 16-session intervention program. Each child’s social engagement was assessed pre-intervention as well as post-intervention in the context of symbolic play in a triad and interaction with an unfamiliar adult. These pre-and post-intervention levels of social engagement were compared in order to detect significant gains after the intervention program with the robot. An increase in both participants’ engaged behaviors during post-assessment measures was observed. One participant demonstrated significantly more engaged behaviors than the other.

Keywords: Autism, Robotics, Joint Attention, TiLar
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Introduction

Joint attention—the ability to share an experience with another person—is fundamental to social engagement (Bruner, 1995). The goal of joint attention is to establish two partners’ mutual focus on a common object, event, or entity (Siebert, Hogan, and Mundy, 1982). In its most concrete form, joint attention involves two people’s focusing on a physical referent. This form of joint attention can be found in early “primordial sharing” interactions (Werner & Kaplan, 1963) as an infant and mother look together at an object (Mundy, Kasari, Sigman, & Ruskin, 1995; Siebert et al., 1982). The definition of joint attention also includes a focus on more covert points of interest such as a concept rather than a tangible object (Tomasello, 1995). It is important to note that joint attention is only classified as such when mutual focus on an object is accompanied by recognition that the interest is shared by a social partner (Baldwin, 1995; Bruinsma, Koegel, & Koegel, 2004). Indeed, a child’s acquisition of joint attentional skills depends upon his ability to associate the affect of a communication partner with his own (Prelock & Ducker, 2006).

Joint attention can be understood by dividing it into progressive levels of sophistication. The first level is the ability to respond to a social partner by following an eye gaze, head turn, or pointing gesture. Following another’s observation in this way is referred to as responding to joint attention (RJA; Mundy & Sigman, 2006; Scaife and Bruner, 1973; Seibert et al., 1982). The second level highlights the child’s ability to initiate joint attention (IJA), using eye gaze, pointing, and gestures to direct the attention of a social partner to a referent of interest (Seibert et al., 1982, Van Hecke et al., 2007). As the child seeks to share an experience with a social partner, his attempts are reinforced by his partner’s emotional response and attention to the initiation (Bates, 1976). Additionally, a child may also elicit the attention of an adult or
caregiver for the purpose of obtaining a desired object or action. This act of directing another’s behavior is called “initiating behavior regulation/requesting” (IBR) by Seibert et al. (1982), and lacks the social impetus inherent in other forms of joint attention (Mundy et al., 2006).

The acquisition of joint attention is a foundational component of a child’s social development. Its role in social development was recognized by Seibert et al. (1982), who included joint attention as one of three essential social domains in their assessment tool, *The Early Social Communication Scales (ESCS)*. Social development leads to social competence, which refers to a child’s ability to respond to her environment in appropriate prosocial ways (Eisenberg et al., 1997; Mundy & Sigman, 2006; Westby, 2010). It involves an individual’s ability to regulate attention, self-monitor and adjust social behavior, and possess positive emotions toward both peers and adults.

The ultimate goal of social development is social competence, which can be loosely described as prosocial behavior (Mundy & Sigman, 2006) due to integrated functioning of three social domains (Westby, 2010). The first domain is secure attachment, which refers to the positive emotional connection an infant has with caregivers. The second domain, instrumental social learning, refers to a child’s ability to connect certain actions and consequences with specific contexts. The third area, experience-sharing relationships, requires that the child base his actions on the behavioral responses of social partners in order to consider others’ points of view, take turns, and develop friendships. When a child exhibits social competence, his actions reflect coordinated proficiency in all three areas.

The link between joint attention and social competence can be explained by at least four conceptual models (See Mundy & Sigman, 2006, for review). Each of the following models acknowledges a joint attentional component of social competence: the caregiving/scaffolding
model, the social-cognitive model, the social-motivational model, and the neurodevelopmental executive model. Researchers base study designs on various models or combination of models as they conduct research on joint attention. For example, some claim that joint attention reflects an integration of social executive and social motivational processes (Mundy et al., 1995), and others equate joint attention with social cognition (Carpenter, Nagell, & Tomasello, 1998).

In addition to its influence on social development, joint attention is an important component of language development as well. Joint attention is a precursor to symbolic communication; specifically, IJA is critical to language acquisition in children (Bruinsma et al., 2004). When a typically developing child can exhibit RJA by attending jointly to a referent of the social partner’s choosing, the child herself then begins to point and establish common referents. Once a child consistently uses the symbolic act of pointing, the more complex symbolic act of using language will soon follow (Westby, 2010). The amount of time children spend in joint attentional interactions has been shown to correlate positively with development of language (Markus, Mundy, Morales, Delgado, & Yale, 2000; Mundy et al, 1995; Mundy, Sigman, & Kasari, 1990).

Due to the substantial influence of joint attention skills on social and language development, the absence of joint attention behaviors during a child’s development is cause for concern. Joint attention skills in children with autism spectrum disorder (ASD), including those with pervasive developmental disorders not otherwise specified (PDD-NOS), are consistently deficient to the extent that absence of these behaviors is used as an early diagnostic indicator (APA, 2000).

Children with ASD demonstrate markedly fewer joint attention acts such as establishing eye contact, using eye gaze shift to share experiences, showing objects to conversational
partners, and pointing, than do typically developing peers (Charman et al., 1997; Mundy, Sigman, Ungerer, & Sherman, 1986; Osterling & Dawson, 1994). In fact, according to Wimpory, Hobson, Williams, and Nash (2000), parents of children with ASD reported fewer joint attention acts in their children than did parents of typically developing children before a formal diagnosis of ASD was given. In addition, the connection between joint attention and language development in typically developing children also holds true for children with ASD. Mundy et al. (1990) found that the variability in use of conventional gestures to establish joint attention among children with ASD was predictive of language abilities after 12 months.

It has been shown that in addition to a reduced frequency of joint attentional acts, children with ASD display reduced amounts of affect during those occasions for joint attention. This lack of affect is hypothesized to be a contributor to the deficit in IJA among children with ASD (Kasari, Sigman, Mundy, & Yirmiya, 1990). Children with ASD neglect to use joint attention for social purposes (Wetherby & Prutting, 1984). Considering the prevalence of these joint attention difficulties, it comes as no surprise that ASD is characterized by impaired social interactions (Kasari, Freeman, & Paparella, 2006).

Given that joint attention forms the foundation for further language skill and social competence, facilitating joint attention should be a primary focus in language intervention prior to addressing communication disorders that may result from joint attentional deficits (Westby, 2010). Westby (2010) underscored the necessity of addressing joint attention in therapy by constructing naturalistic and meaningful contexts rather than by abstract conditioning situations. Constructing an intervention session that qualifies as a meaningful context requires that treatment be motivating and engaging, rich with opportunities for evoking an emotional reaction from the child.
Children with ASD are not as motivated or engaged by social interaction as their typical peers; in fact, they may show more preference for objects than do peers with other developmental disabilities (Prelock & Ducker, 2006). They fail to respond readily and orient themselves to social stimuli (Dawson et al., 1998). For this reason, speech and language intervention designed for children with other developmental delays may not suit the needs of this population. Children with ASD may require more extraordinary effort to elicit social interaction.

In recent years, researchers have considered robots as a possible intervention tool to engage children with ASD. Research findings from a number of labs suggest that children with ASD tend to show a great interest in robots and find them motivating and compelling (Kozima, Nakagawa, & Yasuda, 2005; Robins, Dautenhahn, & Dubowski, 2006; Robins, Dickerson, Stibbling, & Dautenhahn, 2004). In fact, robots may elicit affect from a child with ASD (Kozima et al., 2005), and children with ASD may engage in joint attentional behaviors with the robot (Robins et al., 2005). Despite the success seen in establishing joint attention between a child with ASD and a robot, generalization to interaction with people has not been documented. Indeed, generalization from interactions with the robot to naturalistic contexts remains elusive (Dautenhahn & Werry, 2004; Robins et al., 2005).

The current study sought to promote generalization by using a robot as liaison between a child with ASD and a clinician or caregiver. It was hypothesized that therapeutic activities involving the robot would encourage increased amounts of social engagement, including various types of joint attention between the child and communication partners in settings without the robot. Specifically, changes were noted in the child’s level of engagement during a triadic interaction with two clinicians, as well as an interaction with an unfamiliar adult.
**Literature Review**

In this review, autism spectrum disorder (ASD) is defined. The concept of joint attention is also explained. Typical developmental patterns of joint attention are highlighted, followed by atypical development of joint attention seen in children with ASD. An explanation of the use of robotics in intervention services with children with ASD is also included.

**Autism Spectrum Disorder**

The term ASD refers to a group of pervasive developmental disorders (PDDs) that share common deficits in social interaction and communication, and include the presence of repetitive or stereotyped behaviors (APA, 2000). Complete diagnostic information is included in Appendix 1. The following PDDs fit the criteria for ASD: Autistic Disorder or classic autism, Rett’s Disorder, Childhood Disintegrative Disorder, and Asperger’s Disorder. Each of these disorders exhibits a unique combination of the aforementioned common deficits.

**Behavioral manifestations of ASD.** Diagnostic criteria for ASD depends upon the presence of behavioral manifestations in varying degrees of severity. These behaviors may be present in a variety of combinations as well.

**Impairments in social interaction.** An impairment in social interaction may manifest itself in a child’s inability to use nonverbal behaviors (e.g., eye contact, facial expression, body posture, and manual gesture) to regulate social interactions. It may also be seen in a lack of peer relationships, spontaneous seeking to share enjoyment, or a lack of social-emotional reciprocity (APA, 2000; Prelock & Contompasis, 2006).

The social profiles of children with ASD are rather varied, and researchers have attempted to categorize typical social behaviors that may overlap. For example, Wing and Attwood (1987) proposed a separation of children with ASD into three groups based on social
skills: those who isolate themselves from social interaction, or the aloof group; those who accept
the social approaches of others but do not initiate, or the passive group; and lastly, those who
attempt social initiation, but do so in socially inappropriate ways, or the awkwardly active group.
This classification system is by no means definitive, but demonstrates recent efforts to identify
the heterogeneous social tendencies of this population.

**Impairments in communication.** In addition to social deficits, children with ASD exhibit communication impairments. These communication impairments may result in a delay
or absence of spoken language. Approximately 50% of children who carry the diagnosis of ASD
present with insufficient language for effective communication (Lord & Paul, 1997). Any
spoken language may be limited to repetitive or idiosyncratic speech, and the affect component
of speech may be abnormal or absent (Prelock & Contompasis, 2006).

Furthermore, children with ASD do not employ the use of nonverbal communicative
gestures like pointing and showing to compensate for verbal communication deficits. Mundy et
al. (1990) found that when compared to both mental age-matched and language age-matched
peers with cognitive impairments, children with ASD displayed significantly fewer gestural
behaviors to establish joint attention with communicative partners.

As children with ASD develop, they are less likely to use vocalizations with
communicative intent than typically developing peers, or peers with other cognitive disabilities
(Wetherby & Prutting, 1984). This phenomenon may stem from these children’s ineffective use
of symbolic communication, which requires the user’s successful separation of symbol and
referent. Children with ASD often fail to make this separation and rely instead upon indexical
communication, or reenactment of a situation in which a previous desire was recognized and
met. For instance, rather than using words and gestures that carry symbolic meaning, children
with ASD use the pre-symbolic motor behavior of moving a caregiver’s hand toward a desired object to communicate a need (Wetherby & Prizant, 2000).

Language comprehension may be restricted to literal meanings of words, and pronoun reversals are common. There may be an inability to participate in ongoing conversations with others resulting from confusion of the roles of speakers and listeners (Wetherby, 1986). Make-believe or social imitative play skills may not be age-appropriate, may lack depth, or may not be present at all (Prelock & Contompasis, 2006).

**Presence of repetitive and stereotyped behavior.** Restricted repetitive and stereotyped behavior may result in an inordinately intense preoccupation with certain behaviors, activities, or interests. This preoccupation may be restricted to an intense focus on a single component of an object, such as the propellers of a toy helicopter. Rigid adherence to unnecessary routines is possible, as well as repetitive motor movements (e.g., hand or finger flapping). Known as *stereotypies* or self-stimulatory behaviors, these extraneous motor movements often co-occur with tactile defensive behaviors (i.e. hypersensitivity to benign situations involving touch) and are indicative of an abnormal sensory response to the environment. These stereotypies are presumed to enable a child with ASD to better meet environmental demands by regulating his sensory system (Baranek, Foster, & Berkson, 1997).

**Diagnosis.** Deficits in social interaction, communication, and repetitive behaviors that lead to a diagnosis of ASD are often accompanied by secondary deficits in gross or fine motor skills, attention deficits, hyperactivity, and the presence of seizures (Rapin, 1991). Those who diagnose ASD do so with behavioral criteria, looking for qualitative impairments in the three core deficit areas. If an individual does not exhibit behaviors sufficient to classify him as having ASD, or if the behaviors are present but sub-threshold, the diagnosis of Pervasive Developmental
Disorder Not Otherwise Specified (PDD-NOS) may be given. Indeed, specialists may use PDD-NOS as a diagnostic placeholder until additional diagnostic behaviors are observed (see APA, 2000; and Prelock & Contompasis, 2006).

**Etiology.** The Center for Disease Control and Prevention (2007) states that the prevalence of those identified with ASD in the United States is on the rise, affecting an average of 1 out of every 150 children. This recent increase in ASD has motivated many researchers to search for the source of the condition. Although the etiology is elusive in 95% of diagnoses of ASD, 5-10% of diagnoses can be attributed to chromosomal abnormalities. The fact that more boys than girls are identified with ASD suggests a genetic influence (Rapin, 1991). The possible influence of biological factors has been been confirmed in studies of twins with ASD. When one of an identical pair of twins is identified with ASD, there is a significantly higher likelihood that the second twin will also carry the diagnosis (Bailey, 1995; Folstein & Piven, 1991). The presence of conditions such as Fragile X Syndrome also significantly increases a child’s chances of being identified with ASD.

Although genetic factors have been implicated in ASD, many researchers have investigated the influence of environmental factors such as toxins and viruses on predispositions for ASD. Although no causal relationship has been established, fetal exposure to alcohol, valporic acid, and Cytomegalovirus have been suggested as causal factors. Although food intolerances, immunizations, and abnormal metabolic rates have been implicated as potential causes of ASD, these factors have been dismissed (Prelock & Contompasis, 2006).

**Joint Attention**

Joint attention is foundational to the development of interpersonal communication and a major concern in children with communication disorders. It is of particular importance for
children with ASD, whose diagnosis implies a fundamental deficit in this area. The nature of joint attention and its sequence of development are discussed in this section.

**Nature of joint attention.** Traditionally, joint attention has been defined as the coordination of two partners’ attention on a common referent. The referent of interest can be a tangible object or an abstract concept (Kasari et al., 1990; Mundy & Sigman, 2006; Van Hecke et al., 2007). Sustained interest in an object per se is not considered joint attention; rather, the focus on a referent must be accompanied by consciousness of a communicative partner’s shared interest (Bruinsma, 2004). Furthermore, an awareness of the conversational partner’s affect must also be present. Without this awareness, the infant is not able to actively coordinate joint attention and therefore cannot be considered a communicative partner (Baldwin, 1995).

Initially, typically developing infants participate in RJA by responding to a social partner’s eye gaze, head turn, or point. An infant’s ability to respond to the shifting visual orientation of a conversational partner suggests an early awareness that a conversational partner’s perspective may differ from one’s own (Scaife & Bruner, 1973). Children also participate in IJA by using eye gaze, pointing, and gestures to direct the attention of a social partner to a referent of interest (Seibert et al., 1982; Van Hecke et al., 2007). Bates (1976) recognized this behavior as a child’s independent desire to set an object apart from its surroundings and labeled it a *protodeclarative act.* This behavior is noteworthy because it reflects a child’s desire to seek the attention of another person and share an experience (Mundy & Newell, 2007). As the child seeks to share an experience with a social partner, his attempts are reinforced by his partner’s emotional response and attention to the initiation (Bates, 1976).

Additionally, a child may also elicit the attention of an adult or caregiver for the purpose of obtaining a desired object or action. This act of directing another’s behavior is called
“initiating behavior regulation/requesting” (IBR) by Seibert et al. (1982), and lacks the social impetus inherent in other forms of joint attention. Children exhibiting this behavior do so without regard for the emotional state of the conversational partner (Mundy et al., 2006). Bates (1976) referred to behaviors of this type as protoimperative acts.

The presence of joint attentional acts depends upon a child’s innate propensity to attune herself to others’ expressions of interest and emotion. Typically developing children are born with an awareness of others’ internal states as separate from their own (Tervarthen & Aitkin, 2001). This concept is referred to as intersubjectivity, and Westby (2010) calls it an “interfac[ing] of mind” with a communicative partner (p. 136).

As early as 2 months of age, infants demonstrate intersubjectivity as they and their parents mutually regulate each other’s affective states while looking and listening to each other. The rhythmical vocal, facial, and gestural expressions of both infant and caregiver reflect a reciprocation of affect (Brazelton, Tronick, Adamson, Als, & Wise, 1975). This preliminary cognitive interfacing between infant and caregiver is called primary intersubjectivity. According to Westby (2010), RJA is included in primary intersubjectivity. It precludes secondary intersubjectivity, which emerges around 9 months, when an infant coordinates focused attention on an object with a communicative partner (Tervarthen & Aitkin, 2001).

According to Baldwin (1995), intersubjectivity observed during the secondary stage is true intersubjectivity because a child in this stage is actually aware of the communicative partner’s participation in the experience. Both IJA and IBR are types of secondary intersubjectivity (Westby, 2010). Secondary intersubjectivity forms the underpinnings of theory of mind, or recognition of another’s “experience of emotion” (Westby, 2010, p. 137). A child’s acquisition of theory of mind is a reflection of a child’s maturing social concept. Theory of mind
allows a child to begin to predict a communicative partner’s emotional reaction to an event and subsequent behavior. This predicting process is crucial to a child’s effective participation in social interactions (Westby, 2010) that lead to social learning (Mundy & Sigman, 2006).

Secondary intersubjectivity leads to an infant’s emergence as a partner in a communicative exchange, because he is now aware that his communicative partner is capable of understanding his communicative signals, and subsequently begins intentionally communicating. This intentional communication is measured by increased eye contact, more skilled use of eye contact, an increase in gestures to convey meaning, as well as the presence of strategies to repair communicative breakdowns (Mundy, 2006) in children who enter the secondary intersubjectivity stage. And it is intentional communication that leads to language acquisition (Tomasello, 1995; Westby, 2010).

**Sequence of development.** Joint attention begins to develop in infancy as a child coordinates attention between herself, a communicative partner, and an object of interest. To coordinate attention, infants use joint attentional acts such as eye gaze, pointing, and showing gestures. These actions begin to develop from the initial foundation of intersubjective interactions as children’s focus begins to shift to objects (Kasari, 1990; Mundy et al., 1995). According to Kasari et al (1990), this shift usually occurs around 6 months of age. It is of worth to note, however, that Seibert et al. (1982) recognized that before 2 months of age, an infant can orient to and fixate on a given stimuli, and included this phenomenon as ESCS level 0. They reported that at 2 months of age, infants are able to attend to objects that caregivers conspicuously put in the infant’s line of vision.

Between 2 and 7 months, a child can respond more readily to an object presented slowly within the child’s line of vision, and the child is able to directly initiate joint attention with eye
contact directed at the caregiver while the infant holds and manipulates an object. The ESCS classifies this behavior as level 1 joint attention.

Level 2 joint attention behaviors begin to be seen between 5 and 6 months, but infants do not master these skills until 8-12 months. An infant has entered this stage when a communication partner can direct his attention by pointing and making contact with an object. The infant follows the communication partner’s line of regard, but will only look at the pointed finger, rather than the object of interest. At this stage, an infant begins to point, but does not make any other verbal or gestural attempts to orient the communication partner. Alternating eye gaze can be seen in this stage. Extended periods of joint attention, such as book reading, also begin in this stage.

Just before a child’s first birthday, joint attentional behaviors expand to include more gestures and vocalizations that serve to orient a communication partner. This period of time, extending to a child’s 21st month, is referred to as stage 3 joint attention in the ESCS. A child may use a word, such as an object’s name or an attribute of a picture, to direct her partner’s attention. In addition to improvements in IJA, RJA also improves as a child becomes more skillful at coordinating attention between objects and people. Throughout this stage of joint attention, children more reliably respond to partner’s bids for attention, and are even able to focus on objects at a distance.

Stage 4 joint attention begins at age 20 months and is usually fully developed by 22 months. At this stage, a child has a well-formed symbolic reference system that allows her to participate effectively with a communication partner and refer to objects both in and out of view. A child’s rapidly increasing lexicon also allows for more mature symbolic references (Seibert et al., 1982).
The Use of Robot Technology in Intervention for Children with ASD

Humans generally have a positive perception of robots and their potential integration into everyday routines (Ray, Mondada, & Siegwart, 2008). Preliminary investigations with children with ASD suggest that these children tend to be more than just accepting of robots. In fact, they find them fascinating, engaging, and motivating, and tend to prefer interacting with them over interaction with another human (Kozima et al., 2005; Robins et al., 2004; Robins et al., 2006). This preference for robots has lead researchers to investigate the use of robotics in intervention services for children with ASD.

Although robot designs range from dinosaurs to “garbage cans on wheels,” (Goodrich, 2010), the robots people find to be most engaging are those with anthropomorphic characteristics. Giving a robot a face is an essential component of anthropomorphism: those who interact with a robot with a face are more likely to expect the robot to have a human-like personality and treat it in socially appropriate ways (Edsinger, O’Reilly, & Breazeal, 2000). Within the parameters of anthropomorphism, however, robot designs vary in their approximation of the human form. Some attempt to duplicate human features, while others take on an iconic or cartoonish form, in which the minimum amount of features required to be expressive are used. Still other designs are classified as abstract, exchanging human-like qualities for a more mechanical design and emphasizing the robot’s function (Duffy, 2004). Among these designs, robots with a more human-like appearance are more readily accepted. However, as a robot design more closely approximates a human, there comes a point where the similarity becomes disconcerting and is no longer pleasing. This phenomenon is referred to as the uncanny valley (Mori, 1982)
Children with ASD have been shown to interact with robots in a manner different from their typically developing peers (Campolo et al., 2008; Gomes, 2005; Scassellati, 2005). For example, Gomes (2005) reported that children with ASD will remain focused on a robot’s head long after their typically developing peers have lost interest. Others report that children with ASD are more likely to respond socially to a robot without facial features than to a robot with facial features (Robins et al., 2006). Some researchers have suggested that a high level of focus on or interest in robots may eventually be used as a tool to identify ASD at an earlier age.

Another area of interest is the use of robots to improve responsiveness in children who have already been diagnosed with ASD (Dautenhahn & Werry, 2004). Recent research has sought to customize robots for use in social communication therapy. Robots suited for this type of therapy are designed to be social actors whose purpose is to follow social routines to create relationships with humans (Dautenhahn, 2003).

Lee, Toscano, Stiehl, and Breazeal (2008) reported that in order for a robot to promote responsiveness in an intervention setting, the robot must be able to respond to the child’s bids for attention. It should also be able to attend jointly to an object with the child. The operator of the robot needs to be able to obtain multi-modal information from the joint attention interaction to determine what the robot should do next. Despite the complex demands for the robot’s responsiveness in an interaction, its operation should be intuitive, allowing for forms of gestural, visual, and verbal expression that approximate the depth of human emotion. Ideally, if a robot is to interact with a child in an intervention setting, the child should be able to attribute a personality to the robot as well.

Dautenhahn (2003) noted that a robot intended for intervention can serve in one of three capacities. It can act as a persuasive machine that can be used as a tool to teach basic social
communication skills. The robot might also serve as a social mediator, encouraging interaction between a child and a communication partner. For children who do not learn implicitly taught social skills, the robot might be a social actor who demonstrates basic social skills. The robots referred to in this section represent these three categories in varying degrees.

Some researchers have focused on creating autonomous robots that interact with children with ASD. For example, Michaud and Theberge-Turmel (2002) conducted research using a robot shaped like a sphere that could interact independently with a child with ASD. The robot did not require a controller to issue commands, and therefore did not require that a communication partner be present during social interactions with the child and the robot. Although Michaud reported anecdotal evidence of socially appropriate behavior toward the robot, the emphasis was not on promoting transfer of these behaviors to a communication partner.

Perhaps the most prominent research group involved in using robots to increase responsiveness is the Adapted Systems Research Group at the University of Hertfordshire. Their studies to evaluate the potential for using robots in social interaction with children with ASD are carried out through the AURORA project. An overview of the AURORA project’s research goals are outlined in Dautenhahn (2003). They observed children with ASD ages 7-12 and described the behaviors of these children while interacting with a robot. The Aurora project depended upon unstructured scenarios in which the child was free to choose the method of interacting with the robot; additionally, the child could choose in what position he wanted to interact with the robot (e.g. standing, sitting in a chair, lying on the ground, etc.).

During the initial phases of the project, children with ASD were given the opportunity to interact with a robot designed as a truck. In some instances, children played by themselves with
the robot. In other instances, children played with the robot in pairs. Adults were present for all scenarios. Subsequent analysis of these children’s behaviors revealed the following:

1. Robots are safe for children.
2. Children aren’t afraid of the robot
3. Children wanted to interact with the robot for 10 minutes or more.
4. Children were more interested in the robot when its behaviors were reactionary rather than simply repetitive and non-interactional.
5. Children were able to adapt to the robot’s actions, despite the unpredictable nature of its reactionary behavior.
6. Most children showed more interest in the robot than in a similar-looking but non-robotic toy. This interest was measured by eye gaze and attention to the object of interest.

Other robots have also been used in the AURORA project for imitation and turn-taking interaction. Whereas the robot in the initial AURORA studies was a truck design, the robots used in subsequent AURORA studies had anthropomorphic qualities. Robota, a doll equipped with motors and imitative capabilities was used in interactions with children with ASD and a teacher. The children with ASD who participated in this study exhibited signs of engagement and imitative behavior toward the robot in the interaction. There is also anecdotal evidence that children were seen communicating with an accompanying adult about Robota (Robins et al., 2004).

Another anthropomorphic robot, whose name is an acronym standing for Kinesics and Synchronization in Personal Assistant Robotics (KASPAR), was used to teach facial expressions to children with ASD. KASPAR’s facial expressions, although they approximated those of a
human, were less dramatic than a human’s facial expressions. The facial expressions KASPAR produced were also more consistent than those of a human. Anecdotal reports indicated that the children with ASD were interested in sharing the experience of KASPAR with the researcher in the room. (Cole, 2007)

Aside from the Adaptive Systems Research Group, other groups have been interested in using robots to address recognition of emotions and facial expressions in children with ASD. Researchers at the University of Pisa used a life-like humanoid facial automaton for conveying emotions (FACE) to evoke joint attention and emotion recognition in children with ASD (Pioggia et al., 2005). Four subjects, ages 7-20 years, were reported to spontaneously imitate the facial expressions of FACE, and to make eye contact with it (Pioggia et al., 2007).

Other labs have studied the use of robots in social communication intervention with children with ASD. The Viterbi Lab at the University of California developed a bubble-blowing robot with anthropomorphic features. They found that children were more responsive to the robot when it responded contingently to their behaviors than they were to a robot with random actions (Feil-Safer & Mataric, 2008).

At the National Institute of Information and Communications Technology in Japan, two robots were used during interactions with children with ASD. One robot called Infanoid was the size of an average 4-year old, had eyes that could fixate on an object of interest to establish joint attention, and arms with hands and fingers that could grasp objects. It was found that the children who interacted with this robot moved through phases of neophobia, exploration, and interaction, reflecting each child’s growing concept of Infanoid as a social agent (Kozima & Nakagawa, 2005).
The second robot used by Kozima and Nakagawa (2005) had anthropomorphic characteristics, but unlike Infanoid, was not humanoid. It was called Keepon, and resembled a yellow snowman with two segments. Although the simple face was not capable of showing emotion, its body conveyed emotion by bobbing and rocking. In a longitudinal study lasting three years, children with ASD interacted with Keepon during their time at a daycare center. These children were accompanied by their caregivers during these interactions. Children who participated in interactions with Keepon were reported to spontaneously engage in dyadic interactions with the robot, and at times, engage in triadic interactions with the robot and caregiver.

Current research suggests that children with ASD show positive social behaviors while interacting with robots and that there is great potential incorporating robotics into intervention with this population. Children with ASD are attentive, show positive affect, and participate in imitation sequences during these interactions. However, many researchers involved in developing robots for use in a therapeutic setting are primarily those with computer science backgrounds, who focus on the design of the robot rather than establishing quantitatively the impact of the robot in intervention. Rather than focusing on optimized therapy for children with ASD, their intention is primarily to “bridge the gap between computer and behavioral study” (Goldsmith & LeBlanc, 2004, p. 172). Generalization of promising behaviors from a child and a robot to interactions between a child and communication partner is minimal. In the event that a behavior seen during interactions with the robot has also been seen in interactions with a human, it is only reported through qualitative and anecdotal measures (Dautenhahn & Werry, 2004; Kozima & Nakagawa, 2005; Robins et al., 2005).
Method

Participants

Two boys followed by the Brigham Young University Speech and Language Clinic participated in the study. Each boy exhibited social communication delays due to significantly low levels of both verbal and non-verbal communication. Each boy had been enrolled in special services but had shown limited progress with respect to language and social functioning during the previous year. The participants will henceforth be referred to as Alex and Chris.

Alex. Alex was age 3:7 at the commencement of the study. He was initially diagnosed with hypotonia and developmental delay by a pediatric neurologist. At age 2:5, Alex was assessed further by a psychologist, who confirmed the identification of PDD-NOS and noted borderline IQ, language delay, sensory problems, and gross motor delays on the Autism Diagnostic Observation Schedule (ADOS). Alex’s mother reported the following information regarding his developmental and language history in clinical intake forms completed in January of 2009 when Alex was 2:6.

Birth, medical, and developmental history. Alex was the 6th of 7 children in his family. His prenatal history was unremarkable, with gestation lasting 38 weeks. His subsequent medical history was also uneventful with no physical ailments. Alex’s mother was 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 first sat up at 6 months, crawled at 14 months, and walked at 27 months. At the time of the current study, his gross motor skills continued to be delayed. 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. Results of a hearing evaluation at 3:6 years were consistent with normal hearing levels.

*Speech and language development.* Alex’s first words were *dad* and *tub* at 20 months, but he stopped using verbal language soon after and was nonverbal at 30 months. Although his receptive language skills at the time of study surpassed his expressive language skills, both were limited. Alex responded appropriately to some commands such as *let’s go*, but did not respond appropriately to others such as *eat, sleep, stop, wait, come,* etc. He communicated by grunting and leading his mother by the hand to what he wanted or needed.

Alex had no family history of speech, hearing, or language problems. Although two of Alex’ brothers did not talk until they were over 2 years old, they did not exhibit any subsequent speech or language delays. A paternal cousin was diagnosed with Asperger syndrome, a paternal aunt had spina bifida, and a paternal grandfather had a history of motor delays.

*Social development.* Although Alex’s siblings enjoyed interacting with him and entertained him during activities, he did not play cooperatively or reciprocate during play routines. He required the constant attention of a parent or other caregiver to navigate social situations such as play groups and nursery at church, but he did not engage with these caregivers in social activities. Alex enjoyed solitary motor activities such as running, jumping, listening to music, and being outside.

The psychologist who diagnosed Alex noted that Alex seemed to have a social interest in people, but that he did not engage in interactive play or initiate social routines requiring joint attention. He cried when frustrated, tired, or separated from his mother. He reacted with a positive vocal squeal to exciting stimuli.
**Education.** Since 10 months of age, Alex had participated in early intervention with a local early intervention program, receiving speech, language, and physical services once a month. This intervention program followed a consultation service model, working with Alex as well as with his parents.

Alex began attending his school district’s preschool for children with special needs in September 2009. This preschool also included typically developing children. He initially had difficulty adjusting to school and separating from his mother. He did not participate in preschool routines, he cried excessively and at times was inconsolable. As a result, he attended preschool for 2 of the 4 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. However, his tolerance for school routines gradually improved, and at the time of study Alex attended preschool 4 days per week for the entire 4 hours. Alex exhibited an emerging awareness of school routines, and his peers began to stop calling him the baby. Despite his adjustment to preschool, Alex continued to ignore his peers’ attempts to include him in social interactions, and he did not initiate any interactions with peers. Social communication with teachers was limited to non-verbal requests for drinks and snacks.

**Speech and language services.** Alex began attending a special education preschool in September of 2009 at the age of 2:8, where he received speech and language services at the time of study. Alex had been seen at the BYU speech and language clinic since age 2:8 with a 6-week break from June-September 2009.

Alex’s individualized education plan (IEP) as of September 2009 included goals identical to those from his 2008-2009 IEP, indicating that he had made minimal progress. Specialists at Alex’s preschool provided intervention services on a small group level within the
context of school routines. Alex’s speech-language pathologist also provided individual intervention for 30 minutes per week. The goals included a) pointing to colors, b) naming shapes, c) demonstrating awareness of the concepts of *same* and *different*, d) initiating and maintaining interactive play for 10 minutes, e) attending to a structured activity of the teacher’s choice, f) participating in classroom routines, g) improving receptive language as demonstrated by awareness of safety words and following 1-step commands, and h) using hand signs to communicate.

Intervention services at the BYU speech and language clinic followed an interactional approach. Alex’s clinicians provided structure to sessions by using a picture schedule to organize activities sequentially. Within activities, the clinicians attempted to engage Alex socially during child-directed play. Alex’s goals at the BYU speech and language clinic during the time of study were similar to those of the previous semester, indicating minimal progress. For both semesters, goals included a) extending the duration of interactive play, b) improving symbolic play skills, b) improving joint attention as demonstrated by initiation of activities and tolerance for turn-taking, c) improving comprehension of safety words, and d) improving verbalization of alphabet letter names.

In addition to these goals, Alex’s clinician at the time of study included a) improving pointing skills, b) associating family members with their names, c) improving verbal usage of the words *more* and *please*, and d) using signs or verbalizations to communicate *water*, *hungry*, *yes*, and *no*. Alex’s goals for the spring preceding the study (5/2009-6/2009) were a) imitating simple commands, and b) improving joint attention as shown by his playing with his clinician and mom for 5 minutes. For a complete description of Alex’s speech and language goals, see Appendix 2.
**Chris.** Chris presented with a history of ASD and attention-deficit hyperactive disorder (ADHD). He was the 3rd of 4 boys. His age at the time of study commencement was 7:11. Chris was diagnosed with ASD at age 4 by a child psychiatrist at a regional medical center in January 2004. The following information was gathered from BYU speech and language clinic intake forms completed by his mother on 8/15/2006, as well as from his most current IEP.

**Birth, medical, and developmental history.** Chris’ mother reported an uneventful prenatal and neonatal history. Apart from being diagnosed with ADHD at age 3, further relevant medical history was unremarkable. He first sat up at 6 months, crawled at 8 months, and walked at 9 months. As of 48 months, he was not toilet trained and could not dress himself independently. At the time of the current study, Chris walked and ran, but exhibited overall delay of both fine and gross motor skills. His adapted physical education teacher at school emphasized Chris’s improvement in participation during physical activities rather than skill development in those activities, indicating Chris’s difficulty with engagement in social routines. Chris had no history of hearing deficits.

**Speech and language development.** Chris spoke his first words at 12 months, and communicated at the time of study with short 2 to 4 word carrier phrases such as *I want* or *time for* followed by the desired object and the word *please*. His communication was restricted to communicating basic wants and needs. Chris had a small repertoire of simple signs (e.g. *more*), but rarely used them to communicate. Instead, Chris communicated dislike by screaming. He often needed prompting to verbalize and exhibited echolalia. He said *please* independently, but did not speak in full sentences unless directly prompted and given extra response time. At the time of study, Chris was beginning to demonstrate an awareness of sound-to-letter correspondence.
**Education.** Chris attended a preschool for children with ASD for 2 years before beginning kindergarten. At the time of study, Chris was in his second year of public education in his local school district. He had been in the same teacher’s self-contained classroom for both years and attended 5 days per week.

**Social development.** Chris did not interact with others during constructive play. He was aware of the presence of family members, but did not socially interact with them. Chris needed prompting to look others in the eye and communicate. Teacher report indicated that he hovered at the teacher’s station during free play and preferred the company of adults. At school he had demonstrated some awareness of the emotional state of his peers (e.g. commenting “she crying”); however, he did not play or interact frequently with other children and he did not have friends in his classroom.

**Speech and language services.** Chris began receiving services for speech and language at a preschool for children with ASD at age 3. At the time of study, he was receiving intervention services from the school speech-language pathologist at his elementary school. He received these services in a group setting model using the picture exchange communication system (PECS). Intervention included an apraxia program, although Chris had never been identified with apraxia. Chris’ IEP goals for speech and language at the time of study addressed a) verbally expressing wants and needs within an academic setting using 2-3 word phrases, and b) producing single syllable target words when given a visual cue. Chris’ IEP goals for speech and language from the previous year addressed a) making requests independently and b) producing single syllable words.

Chris had received supplementary speech and language services from the BYU speech and language clinic intermittently since September 2007 at age 5:6. He attended consistently 2
times per week from September 2007 to May 2008. He was again seen in the clinic for a 6-month period from January 2009-June 2009, and then again during a 4-month period from January 2010-May 2010. Intervention in this setting focused on improving social communication through child-directed activities. These activities were pre-planned and sequenced using a visual schedule. Chris’ goals at the BYU speech and language clinic during the time of study were similar to those of the previous year, indicating that he had not mastered the desired skills. His goals included a) improving his level of engagement during activities with a conversational partner as shown by eye contact and following a model during structured activities, b) improving constructive play as shown by his engagement in reciprocal play, and c) increasing expressive language by making spontaneous comments and using three-word utterances to communicate preferences. For a complete delineation of Chris’ goals, see Appendix 3.

Procedure

The current study is part of a pilot study designed to investigate the use of robot technology as a tool to enhance the social engagement and joint attention of children with ASD. A 10-15 minute interaction with an upper body humanoid robot (Troy) was added to participants’ regular treatment sessions. Pre- and post-treatment assessments were performed in the context of a triadic interaction with student clinicians as well as a dyadic interaction with an unfamiliar adult.

Pre-treatment measures. Pre-treatment measures were conducted over two 50-minute sessions before beginning treatment with the robot. For Chris, the assessment sessions were conducted over two consecutive days on 2/1/2010 and 2/2/2010. Due to session recording difficulties, Alex’s assessment sessions were conducted 8 days apart, on 2/4/2010 and
2/12/2010. Each session was recorded using two cameras with different perspectives. One stationary clinic camera captured the majority of the activity in the therapy room. The second was a Canon VIXIA HG21 camera with a 12x optical zoom and was used to record the participants’ facial expressions and body movements.

The triadic interaction assessment was conducted with each participant’s graduate student clinician acting as primary clinician and another graduate clinician acting as secondary clinician. The clinicians attempted to engage the child in a triadic interaction using the following materials: a push car, a tambourine, a music-making hand-operated toy, and a ball. During each elicitation trial, the primary clinician performed an action, such as pushing the car, hitting the tambourine, pushing a button on the hand-operated toy, or throwing the ball. The secondary clinician performed the same action. The primary clinician then invited the child to participate by saying “you do it” or “your turn.” If the child participated, the clinicians attempted to sustain the interaction until the child stopped responding to bids to interact or put the toy in a bin designated as the all done bin. If the child did not participate, the clinicians repeated the initial sequence two or three more times until it was clear that the child would not enter the interaction. The triadic interaction assessment continued until attempts to engage the child had been made with each toy. The target length of this assessment was 10 minutes.

The unfamiliar adult assessment was structured similarly to the Early Social Communication Scale procedure as reported in Kasari, Freeman, and Paparella (2006). An unfamiliar adult attempted to engage the participant in play for 20 minutes. The following were materials available to the unfamiliar adult during the interaction: wind-up and hand-operated mechanical toys, a hat, a comb, glasses, a ball, a car, a balloon, and a book. The unfamiliar adult also sang two songs to the child: Popcorn Popping on the Apricot Tree and The Eensy Weensy
During this assessment, the unfamiliar adult attempted to elicit the child’s attention by waiting for a response or reaction to mechanical toys, the ball, truck or song. If the child showed interest, the adult attempted to maintain joint attention by repeating the action or offering the child a turn. If the child failed to respond to three elicitation attempts, the unfamiliar adult transitioned to another toy or activity. The target length of this assessment was 10 minutes.

**Treatment sessions.** Following initial assessment procedures, 16 treatment sessions were conducted during a 3-month period from February to May. Participants were seen 50 minutes twice a week. Sessions were consecutive except for cancelations due to participant illness or clinic holidays. During each session, 40 minutes were devoted to intervention following approaches from previous clinic treatment plans. Ten minutes of each session were devoted to intervention with the robot. These 10-minute segments were randomly placed at the beginning, middle, or end of each intervention session.

**The robot.** The robot used in this study was a 15-lb upper-body humanoid robot created by graduate students in the BYU Department of Mechanical Engineering. The robot was referred to by the collaborative team and clients as *Troy*. The following information was taken from the creator’s description of Troy (Ricks, 2010). Troy was designed to be the same size as an average 4-year-old child. It was 25 inches tall with two arms 12 inches in length.

Troy’s arms, designed to move much like a human arm, had four degrees of freedom (DOF) per arm. These DOF allowed the following motion in the arms: a) the ability to be raised and lowered, b) adduction and abduction, c) medial rotation of the forearm, and d) extension and flexion of the elbows. The arm movement was made possible by four pairs of RC servo motors in the torso, shoulder, and elbow.
In addition to actuated arms, Troy was equipped with a 7-inch computer screen encased in plastic serving as its head. A simple face was presented on the screen and could be changed to display happy, sad, or neutral emotions. The screen was attached to the body with 2 RC servo motors, allowing 2 DOF in head movement, along horizontal and vertical planes.

A speaker was also placed within the torso, allowing Troy speaking and singing capability. A student from BYU’s music-dance-theater program recorded customized greetings for each participant (e.g. “Hello Chris!”), and the words to familiar songs (Popcorn Popping on the Apricot Tree and Three Little Monkeys Swinging in a Tree). Positive affect sounds (e.g., “Woo hoo!”) and negative affect sounds (e.g., “Whoops!”) were also recorded by the mechanical engineering department.

Troy was mounted on a base to provide stability while on the floor, and was meant to be placed at a child’s eye level. It was connected to a laptop computer via cords extending from the posterior torso. The laptop computer was placed on a countertop during the current study, out of participants’ immediate reach.

Clinicians pre-programmed desired action, sound, and facial combinations using a visual programming graphical user interface developed by BYU’s computer science department. Once appropriate sequences were programmed, a clinician controlled the onset of the desired sequences with a Wii™ remote wirelessly connected to the laptop. When necessary during clinical sessions, the clinicians attached the remote to the underside of a clipboard used to take data, thereby keeping it out of the participants’ line of vision.

Troy’s design allowed the following actions to be used as needed during the 16 treatment sessions: wave hello with the right arm, raise both arms upward simultaneously, push forward
with the left arm, tap downward once, tap downward multiple times, and blow a kiss.

Customized actions for songs were also created.

**Protocol.** The first 2 sessions with Troy were conducted in the same room as typical intervention activities, thereby providing a period of acclimation for participants. The remaining 10-minute robot intervention segments were conducted in a room separate from the room in which the remainder of intervention activities took place. This separation helped eliminate potential robot-induced distractions that may have influenced interaction during other activities.

The room designated for robot activities was 12 x 10 feet (3.66 x 3.04 meters) with ceilings 8 feet (2.44 meters) high. Troy was placed on the ground or on a plastic box providing 6 inches (15.24 centimeters) of elevation. The laptop connected to Troy was placed on a nearby countertop. This placement of the robot allowed the child to see the robot from any point in the room. It also allowed for discreet positioning of computer cables so as to minimize distractions. The participant, clinicians, and when present, the participant’s caregiver, sat on carpet squares in a semi-circle around Troy, with the participant’s carpet square directly facing Troy. Although each participant was allowed time to engage in self-regulatory behaviors and was not obligated to sit in front of the robot, the clinician avoided instigating Troy’s actions until the participant was attentive and had approached his carpet square.

During activities with the robot, the child’s graduate clinician acted as primary clinician, controlling Troy’s actions and directing social interactions within activities. A second clinician was present to support the participant by providing hand-over-hand modeling, prompting the participant to take his turn or attend to another partner, and acting as another social partner when the participant made an effort to include her. Interactions were structured to approximate exchanges such as the following: First, the clinician performed a gesture, such as putting her
hands up, and reacted with positive emotion. The robot then performed the same action and responded positively with sound or motion. The clinician responded to the robot as well, using positive comments such as, “Wow!” The clinician then invited the child to perform the action with a verbal prompt such as, “You do it.” The assisting clinician helped the child via hand-over-hand to perform the same action. When the action was complete, the robot reacted positively to the child with sound or motion.

At occasional intervals, the clinician or robot attempted an action and failed. For example, only one arm might be raised in the air. In this scenario, both the clinician and robot would react with negative affect (e.g. say, “Phooey” or, “Oops, try again”). If the child subsequently performed an action incompletely, the robot and clinician reacted with negative affect.

Materials used to facilitate interaction were a push car, a hand-operated music-making toy, a tambourine, a ball, a felt fishing set, a soft bowling set, and plastic food. Using these materials and Troy’s capabilities, the participants were exposed to triadic or quadratic interactions, with Troy facilitating interaction between the participant and the clinician, and in some instances, a family member. Activities used during treatment sessions were as follows: waving hello and goodbye, pushing a car or truck down a ramp, pushing a car or truck to each other, playing with a tambourine, operating the music-making toy, fishing, bowling, pretending to eat food, singing *Popcorn Popping on the Apricot Tree*, and singing *Three Little Monkeys Swinging in a Tree*.

During each activity, the clinician attempted to engage the child in an interaction routine where the robot, child, clinician, and family member each took successive turns. For a complete listing of target protocol routines, see Appendix 4. The goal was to create an interaction replete
with positive engagement between the child and the clinician or a family member. If the child was unsuccessful in participating in the social exchange (i.e. incompletely executing an action), the robot and clinician would respond with negative affect. When the desired level of engagement was achieved during robot activities, the clinician did not insist that the robot take turns in the interaction.

Specific interventions for the participants. Within the context of established protocol, intervention sessions for each child included client-specific accommodations. These accommodations are discussed in this section.

Specific intervention for Alex. Intervention sessions for the current study began 2/12/2010 and concluded 4/30/2010. During this time, 4 sessions were cancelled due to family illness. Sixteen total treatment sessions were completed. Alex’s mother accompanied him to each intervention session. Because Alex’s mother was interested in intervention strategies, she was incorporated into activities as much as possible. Typical treatment sessions for Alex always involved a picture schedule displaying the day’s sequence of activities; a family picture activity encouraging Alex to associate one letter of the alphabet with the names of each brother and sister; and a motor activity, such as hopping on carpet squares, running around the table, or running down the clinic halls.

Alex’s younger sister, 12 months, was generally also present, usually in a car seat in the therapy room, and was not generally incorporated into intervention activities. At times she walked around the room, but interfered minimally with ongoing activities. Activities usually included in typical treatment sessions were identifying symbols in a book, kitchen play, and car play. Bowling, blocks, songs, bean bags, and baby dolls were sometimes included as activities in the session
Specific intervention for Chris. Treatment sessions for Chris began 2/8/2010 and concluded 5/4/2010. During this time period, seven sessions were cancelled due to Chris’ illness, a family vacation, and a national holiday. Sixteen total treatment sessions were completed. Sessions were 50 minutes in length, with 40 minutes of traditional intervention and 10 minutes of treatment with the robot.

Chris’ sessions always included a bathroom break before the session began; a motor activity, pushing the toy bin from the lobby to the treatment room; a numbered sequence picture schedule, with pictures of activities hidden behind numbers that indicated which activity came first, second, etc.; goldfish crackers and a juice box for a snack, and a book (Chicka Chicka Boom Boom, Who Stole the Cookies from the Cookie Jar, Miss Spider’s ABC’s, Polar Bear, Polar Bear, What do you Hear?, and other counting and alphabet picture books).

Chris’s sessions usually included a building activity with LEGO® blocks or Bionicles®, as well as time spent sitting in beanbag chairs. This was done as a regulatory activity. A tool set, a popcorn popper, Lincoln logs, cars on a track, and a bowling set were occasionally incorporated into therapy activities. Chris’ brothers accompanied him into the therapy room during 3 sessions when Chris seemed poorly regulated. On these days, Chris’s brothers noted that he was having a “bad day.”

Post-treatment measures. Follow-up assessments for both participants were administered during two 50-minute sessions on consecutive days following the 16th treatment session with the robot. The triadic interaction assessment was structured similarly to the initial assessment. The unfamiliar adult assessment was also conducted in a format similar to that of the initial assessment; the same toys and songs were used during pre-treatment assessment were presented to the child during post-treatment assessment. However, in order to preserve the
unfamiliarity of the social partner, an adult other than the initial unfamiliar adult conducted the assessment.

Following post-treatment measures, each participant was allowed one more 10-minute segment with Troy. This final interaction brought the total number of sessions with Troy to 17.

Data Analysis

Each participant’s level of social engagement during pre-treatment and post-treatment assessments was examined. The analysis system used in the current study was patterned after the analysis system used with the ESCS (Seibert et al., 1982). Because participants were older, however, and assessment conditions differed, the categories used in the ESCS were modified. Whereas the participants in the ESCS were restricted to sitting on the lap of their caregiver, the participants in the current study were allowed to move freely around the intervention room, allowing for more varied behaviors.

The current study considered eye contact, imitation, positive affect, and the use of language as key behaviors denoting engagement. The purpose of the engaged behaviors was also considered; participants’ spontaneous use of these behaviors to interact with a communication partner and achieve social goals was classified as initiating engagement. Participants’ use of these behaviors to respond to the actions or comments of a communication partner was classified as responding to engagement.

In addition, periods of non-engagement were noted when participants physically retreated from an ongoing interaction or acted out behaviorally. Physical retreats were coded when the child was at least 5 feet (1.52 meters) from the communication partner without making eye contact, including running to the door or sitting in a corner. Any time the child spent out of the
room was also included in this category. Acting out included crying, screaming, throwing a
tantrum, physical aggression, or self-injurious behaviors.

The frequency of both engaged and non-engaged behaviors was documented. A
complete delineation of the classification system is noted in Appendix 5.

Pre- and post- intervention footage was divided into 5-second segments. Trained coders
viewed each 5-second segment and identified behaviors as those denoting engagement or non-
engagement. As a conservative convention to ensure reliable coding, coders gave an entire
segment the label of non-engagement if any non-engaged behaviors were observed.

After a segment received the label of engagement, coders gave the segment a subset label
of either initiation or responding to engagement. They made this classification by examining
both the segment in question as well as the previous segment to identify what precipitated the
engaged behaviors. If the communication partner did not elicit the behavior, then the segment
was labeled as initiating engagement. If the behavior could be linked to a communication
partner’s action or comment, the segment was labeled as responding to engagement. As another
convention for coding purposes, any segment containing both subsets of engaged behaviors was
labeled as initiating engagement, and any engaged behaviors within the 5 seconds of the segment
were categorized under that subset.

Once the segments received a subset label, occurrences of the specific engaged
behaviors—eye contact, imitation, positive affect, and language—were documented. If observed,
multiple behaviors were documented within a given segment.

Instances of eye contact were coded when the child and communication partner looked at
each other. When eye contact was not clearly visible, eye contact was assumed if the child
looked at the upper part of a communication partner’s face. Eye contact was not coded if the
communication partner did not return the eye gaze. Imitation was coded when the child performed an action or repeated a phrase introduced by the communication partner. The fourth behavior of note, positive affect, was limited to instances of laughter, hopping excitedly, or screaming playfully. If neither engagement nor non-engagement behaviors were seen within a given segment, the segment received the label no behaviors of note. The pre- and post-intervention footage segments were viewed and coded using Final Cut Express software.

To ensure coding accuracy, inter-rater agreement was established with training prior to commencement of coding. Two raters received training on identification of engaged and non-engaged behaviors. Inter-rater agreement of behavior identification in 5 minutes of therapy interaction tapes was reached with 80% accuracy before pre-treatment measures and post-treatment measures were analyzed. After pre-treatment and post-treatment measures were coded, 20% of footage was recoded by a second judge as a confirmatory agreement measure. Judges achieved 89-91% agreement during this confirmatory phase.

Following coding procedures, a descriptive analysis was conducted comparing data from pre-treatment and post-treatment measures to identify any differences in the frequency of engaged and non-engaged behaviors. The total amount of engaged and non-engaged behaviors was counted and graphically represented (see Figures 1-20). Clinical observations of participants’ behaviors were also conducted to capture qualitative changes in social engagement that were not necessarily made evident by the analysis system.

Results

The intent of this study was to identify engaged behaviors in two children with ASD before and after 16 sessions of targeted intervention involving Troy. Behaviors identified as social engagement that occurred within the context of both a triadic interaction and interaction
with an unfamiliar adult were analyzed. Specific behaviors identified as non-engagement were also identified. Pre- and post-intervention measures were taken, and data garnered from these measures were recorded.

Participants’ Performance

The following is a summary of each boy’s performance as measured by frequency of engaged and non-engaged behavior.

**Alex’s performance.** Alex participated in pre- and post-assessment measures evaluating engagement within a triadic interaction and with an unfamiliar adult.

**Triadic Interaction.** Alex participated in a three-way interaction with two adults during pre- and post- assessment. A comparison of the duration of the two assessments, as well as the quantity of behaviors denoting engagement, is presented in this section.

*Pre-intervention assessment.* The duration of Alex’s pre-intervention assessment in a three-way interaction was 3 minutes 50 seconds, divided into 46 five-second bins. During that time, Alex initiated engagement during one 5-second segment with an instance of eye contact. Alex responded to engagement in 10, 5-second segments with eye contact, imitation, affect, and/or language. Four of the 5-second segments were coded as non-engagement, with instances of retreat from interaction and tantrum. Results of Alex’s assessment are listed in Table 1.

Table 1

*Alex’s Results for the Triadic Interaction Assessment*

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Post-intervention assessment. Following the intervention sessions with Troy, Alex’s engagement in a triadic interaction was evaluated again. This evaluation lasted 10 minutes 10 seconds, divided into 122 five-second segments. Alex initiated engagement during eight five-second segments with eye contact. Alex responded to engagement during 44 segments. Alex often used more than one responding behavior per segment, totaling 54 responding behaviors. Alex employed eye contact 39 times, imitation four times, affect two times, and language nine times. Non-engaged behaviors were coded during 11 segments with instances of retreat from the interaction. Results of Alex’s post-intervention sessions are listed in Table 1. Comparisons of engaged to non-engaged behaviors during pre- and post-assessments are graphically represented in Figure 1. A representation of the percentage of the total amount if pre- and post-assessment time during which Alex demonstrated engaged behavior is found in Figure 2. Differences in Alex’s initiating behavior, responding behavior, and non-engaged behavior from pre- to post-intervention are listed in Figure 2. A summary of the frequency of specific initiating behaviors in pre- and post-assessments can be seen in Figure 3. A summary of the frequency of specific responding behaviors in pre- and post-assessments are in Figure 4. Alex’s non-engaged behavior during pre- and post-assessments is in Figure 5.
Figure 1. Length of the assessment in minutes and length of engagement versus non-engagement for Alex’s pre- and post- triadic interaction assessments.

Figure 2. Percentage of assessment with engaged behaviors in pre- assessment versus post-assessment for Alex’s triadic interaction assessments.
Figure 3. Total number of behaviors coded for Alex’s pre- and post- triadic interaction assessments.

Figure 4. Number of initiating engagement behaviors coded for Alex’s pre- and post- triadic interaction assessments.
**Figure 5.** Number of responding to engagement behaviors coded for Alex’s pre- and post-triad interaction assessments.

**Figure 6.** Number of non-engagement behaviors coded for Alex’s pre- and post-triad interaction assessments.
**Unfamiliar Adult.** Alex participated in pre- and post- intervention assessments with an unfamiliar adult. To preserve unfamiliarity, a different adult conducted each assessment. Each assessment’s duration is presented here, as well as a comparison of the quantity of behaviors denoting engagement.

*Pre-intervention assessment.* The duration of Alex’s initial interaction with an unfamiliar adult was 13 minutes 15 seconds, divided into 159 five-second segments. During this time, Alex initiated engagement with eye contact during six segments. Alex displayed behaviors to respond to engagement in 48 segments, using more than one responding behavior per segment. Fifty-nine total responding behaviors were observed. Alex used eye contact 45 times, imitation five times, affect five times, and language four times. Alex displayed non-engaged behaviors during 14 segments by retreating from the interaction and displaying signs of tantrum.

*Post-intervention assessment.* Following intervention with Troy, Alex’s interaction with an unfamiliar adult lasted 23 minutes 35 seconds. During the 283 five-second segments, Alex displayed initiating behaviors during 32 segments. Alex often displayed more than one engaged behavior at a time, using a combination of eye contact, imitation, affect, and/or language to total 55 instances during the assessment. Alex used eye contact 32 times, imitation four times, affect four times, and language 15 times. Alex responded to engagement with 192 behaviors in 146 segments. These behaviors included a combination of each behavior. Alex used eye contact 137 times, imitation 24 times, affect 14 times, and language 17 times. Alex displayed non-engaged behaviors during 15 segments by retreating from the interaction. Alex’s performance during these pre- and post-assessment measures are summarized in Table 2.
Table 2

*Alex's Results for the Unfamiliar Adult Assessment*

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Comparisons of engaged to non-engaged behaviors during pre- and post-assessments are graphically represented in Figure 7. A representation of the percentage of the total amount of pre- and post-assessment time during which Alex demonstrated engaged behavior is found in Figure 8. Differences in Alex’s initiating behavior, responding behavior, and non-engaged behavior from pre- to post- intervention are listed in Figure 9. A summary of the frequency of specific initiating behaviors in pre- and post-assessments can be seen in Figure 10. A summary of the frequency of specific responding behaviors in pre- and post-assessments are in Figure 11. Alex’s non-engaged behavior during pre- and post-assessments is in Figure 12.
Figure 7. Length of the assessment in minutes and length of engagement versus non-engagement for Alex’s pre- and post-unfamiliar adult assessments.

Figure 8. Percentage of assessment with engaged behaviors in pre assessment versus post-assessment for Alex’s unfamiliar adult assessments.
Figure 9. Total number of behaviors coded for Alex’s pre- and post- unfamiliar adult assessments.
Figure 10. Number of initiating engagement behaviors coded for Alex’s pre and post unfamiliar adult assessments.

Figure 11. Number of responding to engagement behaviors coded for Alex’s pre- and post-unfamiliar adult assessments.
Figure 12. Number of non-engagement behaviors coded for Alex’s pre- and post- unfamiliar adult assessments.

**Chris’s performance.** Chris also participated in pre- and post-intervention assessments within the contexts of a triadic interaction and interaction with an unfamiliar adult.

**Triadic interaction.** Chris participated in a three-way interaction with two adults during pre- and post- assessment. A comparison of the duration of the two assessments, as well as the quantity of behaviors denoting engagement, is presented in this section.

**Pre-intervention assessment.** Chris’s initial triadic interaction lasted 4 minutes and was divided into 48 five-second segments. Chris displayed initiating engagement behaviors in six segments with eye contact. Chris responded to engagement in 18 segments, often combining behaviors. 24 total instances of behaviors were observed. Chris used eye contact six times, imitation four times, affect one time, and language 13 times. Chris did not display signs of non-engagement.
Post-intervention assessment. The second assessment of Chris’s triadic interaction lasted 8 minutes 5 seconds, divided into 97 five-second segments. Chris used seven initiating engagement behaviors in five segments. Chris used eye contact two times and language five times. Chris used 47 responding behaviors in 37 segments. Chris used eye contact 22 times, imitation four times, three times, and language 18 times. Nine segments were seen with non-engaged behavior as Chris retreated from the interaction. A summary of Chris’s pre- and post-intervention sessions are listed in Table 3.

Table 3

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Comparisons of engaged to non-engaged behaviors during pre- and post- assessments are graphically represented in Figure 13. A representation of the percentage of the total amount if pre- and post-assessment time during which Alex demonstrated engaged behavior is found in Figure 14. Differences in Alex’s initiating behavior, responding behavior, and non-engaged behavior from pre- to post- intervention are listed in Figure 15. A summary of the frequency of specific initiating behaviors in pre- and post- assessments can be seen in Figure 16. A summary of the frequency of specific responding behaviors in pre- and post- assessments are in Figure 17. Alex’s non-engaged behavior during pre- and post- assessments is in Figure 18.
Figure 13. Length of the assessment in minutes and length of engagement versus non-engagement for Chris’s pre- and post-triad interaction assessments.

Figure 14. Percentage of assessment with engaged behaviors in pre assessment versus post-assessment for Chris’s triadic interaction assessments.
Figure 15. Total number of behaviors coded for Chris’s pre- and post- triadic interaction assessments.

Figure 16. Number of initiating engagement behaviors coded for Chris’s pre- and post- triadic interaction assessments.
Figure 17. Number of responding to engagement behaviors coded for Chris’s pre- and post-triadic interaction assessments.

Figure 18. Number of non-engagement behaviors coded for Chris’s pre- and post-triadic interaction assessments.
Unfamiliar adult. Chris participated in pre- and post- intervention assessments with an unfamiliar adult. To preserve unfamiliarity, a different adult conducted each assessment. Each assessment’s duration is presented here, as well as a comparison of the quantity of behaviors denoting engagement.

Pre-intervention assessment. The duration of Chris’s initial assessment involving an unfamiliar adult was 8 minutes 15 seconds. This time was divided into 99 five-second segments. During this time, Chris used nine initiating engagement behaviors in seven segments. Chris used eye contact two times and language seven times. Chris responded to engagement with 17 instances of engaged behavior in 11 segments. Chris used eye contact six times, imitation four times, affect two times and language five times. Chris demonstrated non-engaged behavior during 48 segments by retreating from the interaction.

Post-intervention assessment. Chris’s post-intervention assessment with an unfamiliar adult lasted 13 minutes 35 seconds and was divided into 163 five-second segments. Chris displayed 20 initiating engagement behaviors in 13 segments. Eye contact was used five times, imitation was used once, affect was used once, and language was used 13 times. Chris displayed 33 responding to engagement behaviors in 27 segments. Chris used eye contact 22 times, affect four times, and language seven times. Chris demonstrated non-engaged behavior during 20 segments of the interaction, including retreat from the interaction and tantrum. A summary of Chris’s pre- and post-intervention sessions are listed in Table 4.
Table 4

*Chris’s Results for the Unfamiliar Adult Assessment*

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Comparisons of engaged to non-engaged behaviors during pre- and post-assessments are graphically represented in Figure 19. A representation of the percentage of the total amount if pre- and post-assessment time during which Alex demonstrated engaged behavior is found in Figure 20. Differences in Alex’s initiating behavior, responding behavior, and non-engaged behavior from pre- to post-intervention are listed in Figure 21. A summary of the frequency of specific initiating behaviors in pre- and post-assessments can be seen in Figure 22. A summary of the frequency of specific responding behaviors in pre- and post-assessments are in Figure 23. Alex’s non-engaged behavior during pre- and post-assessments is in Figure 24.
Figure 19. Length of the assessment in minutes and length of engagement versus non-engagement for Chris’s pre- and post- unfamiliar adult assessments.
Figure 20. Percentage of assessment with engaged behaviors in pre assessment versus post-assessment for Chris’s unfamiliar adult assessments.

Figure 21. Total number of behaviors coded for Chris’s pre- and post-unfamiliar adult assessments.
Figure 22. Number of initiating engagement behaviors coded for Chris’s pre- and post-unfamiliar adult assessments.

Figure 23. Number of responding to engagement behaviors coded for Chris’s pre- and post-unfamiliar adult assessments.
**Figure 24.** Number of non-engagement behaviors coded for Chris’s pre- and post- unfamiliar adult assessments.

**Clinical Observations**

The overall increase in both initiating and responding to engagement was complemented by the marked improvement in both participants’ social exchanges over the course of the study. Those who were closely involved with the robot intervention sessions (e.g., clinicians, camera operators, and caregivers when present) noted gains in social interaction. Outside of the clinic each participant’s special education teachers and service providers, unaware of the intervention study, also reported socio-behavioral changes in the school setting.

Both participants quickly adapted to session activities with the robot, exhibiting a strong preference for time with Troy. Part of intervention activities with the robot included salutation sequences, with Troy’s waving to the participant and greeting him by name. The participants enjoyed this activity and readily greeted Troy with a similar wave. As the study progressed, both participants began to acknowledge others in the room with a salutatory gesture. Alex then began
to wave goodbye to his clinician at the end of intervention sessions. Chris coupled waving hello and goodbye with a verbal greeting directed at his clinician or others in the room. Chris often included the name of the communication partner as well. He spontaneously greeted the assisting clinician in the parking lot, and finished post-assessment with an unfamiliar adult by spontaneously saying, “Bye. See you later.”

In addition to salutatory sequences, interactions with Troy often included song-and-action sequences as well as emotion recognition activities. Troy was programmed to sing simple songs and perform contingent actions, which the participants often imitated. Because Troy’s design included arms without hands, Troy’s approximations of song actions were often gross arm movements without the refined hand motions that a communication partner (i.e., clinician or parent) would use. For example, the gesture that communication partners used to signify an alligator in *Three Little Monkeys* involved pressing the palms together and veering outward from the body, fingers first, in a serpentine motion. Without palms, Troy’s design simply allowed for adduction of the arms as they swayed back and forth in a parallel fashion. Initially clinicians noticed that Alex used parallel arm motion similar to Troy’s when the alligator was mentioned in the song. However, as sessions continued, Alex began to modify his actions to follow the more intricate hand motions of the communication partner. Succinctly stated, when Troy took a turn singing, Alex imitated Troy’s actions. When communication partners took turns singing, Alex made adjustments to his actions to imitate those of the clinician or parent. This adaptation denoted improved attention and imitation skills.

Troy’s LCD screen face with simple facial expressions proved fascinating, particularly for Chris. Chris noticed changes in Troy’s face from neutral to happy to sad, and often commented on them out to the clinician by pointing to Troy’s face and saying, “Happy?” or
“Don’t cry?” His clinician would then imitate Troy’s face by frowning or smiling, and she would encourage Chris to do the same. As Chris participated in these sequences, he began to demonstrate improved attention to facial features and a greater likelihood of imitating both Troy and his clinician.

Interactions with Troy emphasized turn-taking, as the clinician encouraged the participant to take a turn pushing a truck, playing a musical instrument, or throwing a ball. The clinician would then give Troy time to enact a similar action, whereupon the clinician would take a turn. During pre-assessment measures, participants were encouraged to use these same toys to take turns in a triadic interaction. Neither of the boys chose to engage in interaction by taking a turn during the pre-assessment. During post-assessment, however, both participants spontaneously, independently, and repeatedly pushed a car to a communication partner, displaying significantly improved turn-taking skills.

At times, interaction routines with Troy were hindered by participants’ perseveration on restricted interests. One example was Chris’ insistence on bringing LEGO® men into the room. Chris’ assisting clinician encouraged Chris to show his LEGO® men to Troy. Chris began to do so—the first time his clinicians had observed his tolerance of another entity participating with him in his restricted interest. During post-intervention with an unfamiliar adult, Chris allowed the communication partner to incorporate the LEGO® men in activities, suggesting an expanding concept of others’ inclusion into his restricted interests. As an interesting addition, Chris’s special education teacher reported during a post-assessment interview that Chris had recently begun to show his LEGO® men to a classmate on the playground. This was the first time she had observed Chris engage in social interaction on the playground.
A final improvement noted in both participants’ social exchanges involved more advanced symbolic references. Alex began to use the picture of Troy on his picture schedule to request commencement of activities with the robot. Before intervention with the robot, Alex’s clinicians had not documented his connection of a picture with an activity. Chris’s symbolic references likewise improved as he spontaneously used his LEGO® men to wave “hello” and “goodbye” to the unfamiliar adult during post-assessment measures. His use of an inanimate object to act out social scripts had not been seen before in the clinic.

**Discussion**

The current study was designed to examine the effect of intervention incorporating a robot on generalization of social engagement, including joint attention skills (e.g. eye contact, imitation, positive affect, and language). The robot was used for 10 minutes within 50-minute intervention sessions as liaison between a child with ASD and a clinician or caregiver. It was hypothesized that therapeutic activities involving the robot would encourage increased amounts of social engagement, including various types of joint attention between the child and communication partners in settings without the robot. Specifically, changes were noted in the child’s level of engagement during a triadic interaction with two clinicians, as well as an interaction with an unfamiliar adult.

An encouraging initial observation was that each child’s post-assessment was substantially longer in duration than the pre-assessment. This increase in duration indicated that participants sustained attention to activities for longer amounts of time, and that conversational partners were more successful in regaining the boys’ participation after periods of non-engagement.
As data were examined further, it became apparent that each participant demonstrated an increase in behaviors denoting all forms of engagement during both triadic interaction and interaction with an unfamiliar adult. Initiating engagement improved somewhat, and responding to engagement improved dramatically in each boy’s case. Although it could be argued that an increase in engaged behaviors could simply have resulted from the increase in assessment duration, one should keep the following in mind: The duration of the assessment depended wholly upon the child’s willingness to remain engaged in activities. Had the participant continued to demonstrate engaged behaviors in pre-assessment measures, the assessment would have continued. Furthermore, when considering all assessments apart from Chris’ interaction in a triad, participants’ engaged behaviors amounted to a greater percentage of assessment time in post-assessment measures. This greater percentage translates to an increase of engaged behaviors per minute of assessment. An increase was seen in each participant’s use of combined engaged behaviors in post-assessment measures as well; for example, both children paired eye contact with language or affect more often, an indication of increasingly sophisticated social communication.

Interestingly, non-engaged behaviors also increased in all cases apart from Chris’ assessments with an unfamiliar adult. More non-engaged behaviors could, of course, indicate that the participants were more likely to separate themselves from interactions with communication partners during post-assessment measures and therefore be considered a negative aspect of our findings. The behavioral histories of these two participants, however, suggested that both children required extra time to process emotions and regulate emotional responses: The increased post-assessment duration suggests a greater exposure to emotionally stimulating interactions. Therefore, the increase in non-engaged behaviors could simply be a result of the
children’s attempts to emotionally regulate before returning to an engaged state within the interaction.

In addition to quantitative results found in the data gathered, clinical observation revealed a qualitative improvement in the participants’ social interactions. Use of social scripts, imitation, turn-taking, and symbolic references were all noted to increase.

When comparing the progress of the two participants, Alex’s post-assessment gains are both more dramatic and more consistent. This substantial difference could be due to a variety of reasons. The first reason, and perhaps the most obvious, is age. Alex was five years younger than Chris. At approximately 3 years of age, Alex’s communication behaviors may not have been as ingrained as those of Chris, and this neuroplasticity may have resulted in enhanced susceptibility to social communication intervention. Furthermore, Alex was at a lower developmental level than Chris. Unlike Chris, Alex lacked ability to communicate even simple wants and needs. Perhaps intervention activities were more suited to Alex’s cognitive level.

Another reason for Alex’s greater gains could be due to parental involvement. Alex’s mother consistently accompanied him into session activities with the robot. Chris’s parents, on the other hand, never accompanied him. His two brothers only did so twice. It is possible that the presence of Alex’s mother during robot sessions improve likelihood of generalization of behaviors outside of the therapy room, thereby giving Alex more exposure to situations inviting engagement. Despite these factors, it should be remembered that both children made improvements in their use of behaviors denoting an initiation of engagement and a response to engagement.

The gains seen in both participants are best explained by the 16-session intervention with Troy. Both Alex and Chris had shown little progress regarding engagement in school as well as
in the clinic in previous semesters. For this reason, it seems unlikely that improved social engagement in both boys could be attributed solely to natural development over the course of the study. These gains could be attributed to Troy’s ability to engage both participants: Both children displayed tremendous amounts of positive affect during their interactions with Troy, and were eager to interact with the robot. Such a highly motivating context could have enhanced participants’ desire to participate, thereby leading to greater opportunities for practice of targeted behaviors. Another distinctive feature of this study was the nature of the interactions with Troy. Exchanges were encouraged between the child and the robot as well as between the child and a clinician or parent. This interactive design was intended to draw the child into a social routine with the robot as well as a communication partner. This unique design could also have been a factor in improved behavior.

In addition to interactive sequences, the low-dose nature of these interactions with Troy could also have contributed to increased gains. The current study emphasized a small percentage of total intervention time dedicated to interactions with the robot. This low-dose procedure could have given the child more opportunities to practice engaged behaviors in a controlled intervention setting while removing the robot. In other words, behaviors primed by the robot could have been practiced during typical intervention activities, increasing the likelihood of their use outside of the clinic room.

Aside from the engaged and non-engaged behaviors examined in this thesis, there is a wealth of information to be explored within the 16 sessions centered on the participant and Troy. This valuable footage must be analyzed in an effort to elucidate the aspects of the children’s interactions with Troy that were the most valuable in improving the engagement. For example, Alex’s participation in activities with the robot increased significantly when familiar songs were
included in Troy’s repertoire of actions. Examining Troy’s actions and the progress of the participants would allow for more specific conclusions regarding the connection between intervention with Troy and participants’ progress.

This study was conducted to assess the general effectiveness of using a robot as facilitator to improve social engagement in children with ASD. The positive results of this study suggest generalization of gains in engaged behaviors to settings without the robot. Therefore, more extensive research is warranted to examine these positive gains. As a pilot study, this project employed a case study design. This structure sufficed for pilot purposes; however, to obtain more conclusive evidence, future research should be expanded to include a greater number of participants within a staggered-baseline design. In this way, researchers would better separate robot-induced gains from gains attributable to other factors. In addition, it will be important to identify a population most receptive to this type of intervention as well as factors contributing to the most effective use of a robot.
References


Appendix 1

Autism Spectrum Disorder core deficit areas:

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. a 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 impairments 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 or 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 either in 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

For Autism:
At least two of the social impairment criteria are met;
At least one of the communication impairment is met;
At least one of the restricted repetitive and stereotyped patterns of behavior, interests, and activities criteria is met;
A delay or abnormal functioning is observed in social interaction, language used as social communication, or symbolic/imaginative play prior to age 3; and
Behavior cannot be accounted for as Rett’s or Childhood Disintegrateive disorder

For PDD-NOS:
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.
Appendix 2

Alex Semester Goals Winter 2010

Semester Goals
1. Alex will improve his play skills.

1.1 Alex will attend to an interactive activity for 7-10 minutes with moderate support from the clinician.

Baseline: On January 22, 2010, Alex attended to a book for 30 seconds with his mother. However, he attended to the book for 3 minutes by himself. Alex attended to the ball ramp activity for 5 minutes with his mother and the clinician. Alex attended to a car ramp activity for 10 minutes with the clinician.

Follow-up: On April 29, 2010, Alex attended to an activity (playing with cars) for 8 minutes, to another activity for 5 minutes, and to the robot activity for 12 minutes with minimal support from the clinician. Alex rarely required his mother or the clinician to re-engage him in the activity and he needed minimal probing to take turns with his mother and the clinician.

1.2 Alex will attend to a table activity for 8-10 minutes with moderate support from the clinician.

Baseline: On January 22, 2010, Alex attended to a puzzle activity at the table for 5 minutes.

Follow-up: On April 29, 2010, Alex attended to one table activity with pictures of his family for 5 minutes with maximum support from the clinician. He attended to a table activity (playing with a kitchen set) for 8 minutes with minimal support from the clinician.

1.3 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.

Baseline: During the Westby play scale administered on January 15, 2010, Alex did not participate in symbolic play with any toys. On January 22, 2010, Alex participated in a symbolic play activity with a car and car ramp for 10 minutes with moderate support from the clinician. He did not participate in symbolic play with any other toy.

Follow-up: On April 30, 2010, Alex appropriately played with 3 different toys (bowling set, cars, and a kitchen set) throughout the session with minimal support from the clinician. Alex appropriately plays with the toys with minimal probing from the clinician and rarely needs to be redirected to the activity. Previously, Alex would twirl the bowling pins, roll the cars back and forth with no apparent purpose, and twirled items from the kitchen set. Now, Alex rolls the ball to knock down the bowling pins, pushes the cars to the clinician and pushes them around a toy garage, and pretends to eat toy food by putting the food to his mouth and making appropriate munching sounds.

2. Alex will improve his joint attention.
2.1 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.

**Baseline:** During the Westby play scale administered on January 15, 2010, Alex occasionally made eye contact with the clinician when prompted. On January 22, 2010, Alex made eye contact with the clinician 7 times during a 5-minute interactive activity.

**Follow-up:** On April 29, Alex made eye contact with the clinician approximately 25 times during a 5 minute activity with minimal support from the clinician. It was also noted that Alex has consistently made eye contact with his mother and the clinician throughout the last several sessions. He spontaneously makes eye contact during nearly every exchange during activities.  

2.2 Alex will demonstrate joint attention by initiating an activity three times during a 5-minute activity, with moderate support from the clinician.

**Baseline:** On January 22, 2010, Alex initiated that his mother take a turn 1 time during the ball and ramp activity.

**Follow-up:** On April 30, 2010, Alex initiated an activity with the clinician 4 times during the session with no support from the clinician.

2.3 Alex will demonstrate joint attention by taking 10 turns during a 5-minute activity with moderate support.

**Baseline:** On January 22, 2010, Alex took 5 turns during a 5-minute activity with his mother and the clinician with maximum support from the clinician. Alex frequently required the clinician to use hand-over-hand in order for him to take turns while playing with his mother.

**Follow-up:** On April 30, 2010, Alex took 5 turns in a 4 minute activity with his mother with moderate support from the clinician. Alex willingly takes turns with his mother or the clinician when they say, “My turn.” However, he occasionally needs additional support, such as hand-over-hand.

3. **Alex will expand his receptive language.**

3.1 Alex will maintain his understanding of the following commands: wait, sit down, hold hand, and clean up in 80% of opportunities with minimal support from the clinician.

**Baseline:** On December 11, 2009, Alex’s previous clinician reported that Alex displayed an understanding of these terms, with moderate support from the clinician. Treatment will focus on maintaining Alex’s understanding.

**Follow-up:** On April 19, 2010, Alex cleaned up when his mother and the clinician requested, with minimal support from the clinician.

3.2 Alex will demonstrate his understanding of his family member’s names by pointing to their picture when asked in 8/10 opportunities with maximum support from the clinician.
**Baseline:** On January 15, 2010, Alex’s mother reported that he does not recognize family member’s names.

**Follow-up:** On April 29, 2010, Alex spontaneously produced the names of four of his family members (Mom, Natalie, Zack, and Ellie) when pointing at their pictures during a table activity.

3.2 Alex will identify common objects from a book when prompted in 80% of opportunities.

**Baseline:** On January 22, 2010, Alex’s mother stated a desire for Alex to recognize common objects from a familiar book. She reported that he does not do this now.

**Follow-up:** On April 29, 2010, Alex said the words rabbit (/bIt/), dog (/ag/), and duck (/ʌk/) during a book activity with moderate support from the clinician.

4. *Alex will expand his expressive language.*

4.1 Alex will demonstrate appropriate usage of “more,” and/or “please” in 9/10 opportunities with moderate support from the clinician.

**Baseline:** On Alex produced “more” one time with moderate support from the clinician. However, Alex did produce “please” approximately 10 times with moderate support from the clinician.

**Follow-up:** On April 15, 2010, Alex produced the word “more” approximately 5 times during the session with maximum support from the clinician. Ammon spontaneously produced the words “all done” once during the session with no support or prompting from the clinician.

4.2 Alex will demonstrate the ability to point distally in 8/10 opportunities with moderate support from the clinician.

**Baseline:** On Alex “pointed” distally with all 5 fingers (not just the pointer finger) 2 times with maximum support from the clinician. He pointed with his index finger and touched the actual object 3 times with moderate support from the clinician.

**Follow-up:** On April 29, 2010, Alex spontaneously pointed with his index finger to all 8 pictures of his family members.

4.3 Alex will produce, by signing or verbalizing, “water,” “hungry,” “yes,” and “no” in 8/10 opportunities with maximum support from the clinician.

**Baseline:** On January 15, 2010, Alex’s mother reported that he does not produce these words or signs.

**Follow-up:** On April 29, 2010, Alex appropriately produced the words “yes” and “no” approximately 20 times during an activity with moderate support from the clinician.
Alex Semester Goals Fall 2009

Semester Goals

1. Alex will improve his play skills

1.1 Alex will build onto his play skills by attending to an interactive activity for 7-9 minutes with moderate support.

**Baseline:** On 9.14.09, Alex attended to an interactive toy for 2-3 minutes with moderate support.

**Follow up:** On 11.18.09 and 11.20.09, Alex attended to interactive toys for 7 and 11 minutes with moderate support.

1.2 Alex will attend to an activity while sitting on a chair at a table for 8-10 minutes.

**Baseline:** On 9.18.09, Alex attended to an activity while sitting on a chair at a table for 6 minutes with maximal support.

**Follow up:** On 11.18.09 and 11.20.09, Alex attended to an activity while sitting on a chair at a table for 11 minutes and 7 minutes.

1.3 Alex will expand his symbolic play skills by demonstrating the ability to feed a doll with moderate support.

**Baseline:** On 9.26.09, Alex was able to feed a doll with maximal (hand-over-hand) support.

**Follow up:** On 11.20.09, Alex was able to feed a doll with maximal (hand-over-hand) support.

2. Alex will improve his joint attention.

2.1 Alex will demonstrate joint attention by taking 5 turns during a 3 minute activity with maximal support.

**Baseline:** On 9.14.09, Alex took 1 turn in a 3 minute activity with his mother and clinician.

**Follow up:** On 11.20.09, Alex took 19 turns in a highly motivating activity with maximum support, 2 turns with moderate support, and 1 turn with no support in an 11 minute activity.

3. Alex will expand his receptive language.

3.1 Alex will demonstrate understanding of the following commands: wait, sit down, hold hand, and clean up with moderate support.

**Baseline:** On 9.14.09, Alex’s mother reported that he does not understand these terms.

**Follow up:** On 11.20.09, Alex’s demonstrated the understanding of “hold hand” 1 time, “sit down” 2 times, and “clean up” 4 times with visual support throughout the session.
3.3 Alex will identify (by touching or naming) 3-5 pictures of common household items and toys.

**Baseline:** On 9.25.09, Alex was not able to identify any pictures of common household items or toys.

**This goal was deferred until a later date.**

4. *Alex will expand his expressive language.*

4.1 Alex will verbalize the names or sounds of the following letters: H, L, F, Y, and C.

**Baseline:** On 9.25.09, Alex was not able to verbalize the names or sounds of any of the above letters.

**Follow up:** On 11.20.09, Alex was able to imitate verbalizations of L and F, produce a vowel like construction similar to Y, and imitate the H sound.

4.2 Alex will demonstrate appropriate usage of “more” in 6/8 opportunities with maximum support.

**Baseline:** On 9.25.09, Alex appropriately used the vocalization “mamama” for “more” in 3/7 opportunities with moderate support during the 50 minute session.

**Follow up:** On 11.20.09, Alex appropriately used the vocalization “mamama” for 4 “more” in 7/8 opportunities with moderate support during the 50 minute session.

4.3 Alex will demonstrate the ability to point distally with moderate support.

**Baseline:** On 9.14.09, Alex’s mother reported that Alex did not demonstrate the ability to point distally.

**Follow up:** On 11.18.09, Alex demonstrated the ability to point 8 times with moderate support.

**Alex Semester Goals Spring 2009**

1. *Alex will improve his expressive and receptive language by imitating a simple command with maximum gestural support.*

**Baseline:** 5/13/09 Alex was able to follow simple commands with multiple verbal and tactile cues. He was not able to follow verbal commands. Alex did not verbalize any words, but did vocalize vowel like constructions during his play. 5/20/09 Alex was able to recognize the following letters and verbalize their sounds: “E”, “M”, “Z”, “X”, and “L.” He also was able to discriminate between “T” and “L”.

**Follow-up:** 6/10/09 Alex was able to follow simple commands with verbal and tactile cues. He followed 14 simple commands throughout the session. Alex was able to recognize the following
letters and verbalize their sounds: “E”, “M,” “N”, “L”, “F”, “X.” Alex demonstrated emerging skills for “T,” “C,” and “O.” Alex was also able to match the foam letter “C” to its paper card with only verbal cuing.
Appendix 3

Chris’s Semester Goals Winter 2010

Goal 1 Chris will improve his level of engagement during activities with a conversational partner.
1.1 Chris will make appropriate eye contact 12 times to convey his communicative intent when commenting, requesting, or attending, during a 50 minute session.

Baseline: on 1/26/10, Chris made eye contact on 7 occasions during the session. These occasions included saying hello and goodbye, reading a book, asking for more juice or activities, and while moving his clinician into a funny pose.

Follow-up: on 5/4/10, Chris made eye contact on 48 occasions during the session. These occasions included saying hello and goodbye, making requests during snack time, while playing with Troy the robot, and while playing with legos.

Goal 2. Chris will develop his ability to participate in constructive play.

2.1 Chris will participate in reciprocal play as demonstrated by him following his clinician’s model on 7 occasions during one structured activity.

Baseline: On 1/26/10, Chris engaged reciprocal play with his clinician while playing with legos on 5 occasions. These included following his clinician’s model while putting pieces on the lego, flying lego men around the room, manipulating the arm of the lego back hoe, and making a sound of positive affect while making eye contact.

Follow-up: On 5/4/10, Chris engaged in reciprocal play with his clinician while playing with the robot on 9 occasions. These included singing Popcorn Popping, a monkey song, fishing for Velcro fish, and saying goodbye to the robot and the people in the room with moderate support from his clinician.

Goal 3: Chris will increase his expressive language.

3.1 Chris will use 3-word phrases to communicate wants and needs 15 times during structured activities with moderate support from his clinician.

Baseline: On 1/26/10. Chris used 10 three-word phrases throughout the session, including requesting legos from his clinician and asking for the key to open the cupboard.

Follow-up: On 5/4/10, Chris used 31 three-word phrases throughout the session. These were produced with moderate support from his clinician and independently.

3.2 Chris will make 3-5 appropriate comments while reading a book/or during one structured activity within a 50-minute session.

Baseline: Chris made 9 appropriate comments while playing with legos with his clinician. These included this one, hands, that one, and almost.

Follow-up: On 5/4/10, Chris made 29 appropriate comments while interacting with the robot Troy and his clinician. These were made spontaneously or after a clinician’s model.
Chris Semester Goals Winter 2009

Semester Goals

Goal 1: Chris will make appropriate eye contact to communicate his intent.

Objective 1.1: Chris will make appropriate eye contact to convey his communicative intent when commenting, requesting or attending, 3/5 opportunities within a 50-minute session.

Baseline: Chris made appropriate eye contact 3 times with his clinician during a 50-minute session on 1/14/2009. He made appropriate eye contact at the conclusion of the session when waving good-bye.

Follow up: Chris made appropriate eye contact 8 times with his clinician during a 50 minute session on 4/1/2009.

Goal 2: Chris will develop his ability to play appropriately as demonstrated by the variety, quality, and duration of his play episodes.

Objective 2.1: Chris will participate in purposeful constructive play during a 50-minute session.

Baseline: Chris did not participate in constructive play during a 50-minute session on 1/14/2009.

Follow up: Chris participated in 40 minutes of constructive play on 4/1/2009.

Objective 2.2: Chris will participate in reciprocal play as demonstrated by following his clinician's model 3/5 opportunities during one structured activity.

Baseline: Chris did not follow his clinician's model during his play on 1/14/2009. Follow up: Chris followed his clinician's model 6 times during his play on 4/1/2009.

Goal 3: Chris will increase his expressive language.

Objective 3.1: Chris will use 3-word phrases to communicate his preference between 2 choices, 3/5 opportunities within one structured activity.

Baseline: Chris did not use 3-word phrases to communicate his preference on 1/14/2009.

Follow up: Chris used 18 three-word requests to indicate his preference on 4/1/2009.

Objective 3.2: Chris will make 3-5 relevant comments (e.g., naming pictures) while reading a book or during one structured activity within a 50-minute session.

Baseline: Chris did not make comments during a structured activity on 1/14/2009.
Follow up: Chris made 7 appropriate comments during three structured activities during a 50-minute session on 4/1/2009.

Chris’s IEP goals

2010

Early Learning

1. Chris will write his name, address or phone number when given a verbal or written cue with 90% accuracy for 4/5 consecutive trials, as implemented by the Special Education teacher, without any current achievement, with 90% target achievement.

Objective 1.1 Chris will write his first name when given a verbal or written prompt.

Objective 1.2 Chris will write his last name when given a verbal or written prompt.

Objective 1.3 Chris will write his address when given a verbal or written prompt

Objective 1.4 Chris will write his phone number when given a verbal or written. [sic]

Math

1. Chris will use touch points to add one-digit by one-digit numbers 1-9, when given 10 different problems, with 80% accuracy for 4/5 consecutive trials, as implemented by the Special Education teacher, without any current achievement, with 80% target achievement.

Objective 1.1 Chris will correctly place touch points on numbers 6-9 when given a number and a verbal cue.

Objective 1.2 Chris will use touch points to add one-digit by one-digit numbers 1-5.

Objective 1.3 Chris will use touch points to add one-digit by one-digit numbers 6-9

Objective 1.4 Chris will use touch points to add one-digit by one-digit numbers 1-9.

Reading

1. Chris will read 75 new words when given
Early Learning

1. Chris will demonstrate effective preacademic writing by tracing numbers, as implemented by the Special Education teacher, without any current achievement, with 80% target achievement

Objective 1.1 Chris will trace numbers 1-10 within ½” of the line, when given the verbal cue, “Trace [x]”

2. Chris will demonstrate effective preacademic writing by writing his first name, as implemented by the Special Education teacher, without any current achievement, with 80% target achievement

Objective 2.1 Chris will copy his first name when given the verbal prompt, “Copy your name”.

Objective 2.2 Chris will write his first name when given the verbal prompt, “Write your name.”

3. Chris will demonstrate effective numbers skills by using touch points to complete addition problems using numbers 1-5, as implemented by the Special Education teacher, without any current achievement, with 80% target achievement

Objective 3.1 Chris will independently draw touch points on numbers 1-5

Objective 3.2 Chris will use touch points to complete addition problems using numbers 1-5

4. Chris will demonstrate one to one correspondence, as implemented by the Special Education teacher without any current achievement, with 80% target achievement.

Objective 4.1 Chris will count 1-10 objects when given the verbal cue, “Give me [x]?”.
5. Chris will demonstrate effective reading skills by reading 150 sight words, as implemented by the Special Education teacher, without any current achievement, with 80% target achievement.

Special Education

1. Chris will demonstrate effective control of body movements, as implemented by the Special Education teacher, Adapted PE Specialist

Objective 1.1 Chris will participate in two warm-up activities with only one prompt per activity.

2. Chris will demonstrate effective ball bouncing and general ball skills, as implemented by the Special Education teacher, Adapted PE specialist

Objective 2.1 Chris will receive a ball and give it back w/o prompts 2/5 (throw/catch, kick, roll, bounce).

3. Chris will demonstrate effective visual motor skills as an Individualized Educational Plan goal, as implemented by the Special Education teacher, enabling him to progress in the curriculum, in a small group setting, without any current achievement, with 80% target achievement.

Objective 3.1 Chris will cut out basic shapes within ½” of the line

Language and Speech

1. Chris will appropriately and independently make requests (using speech, sign language or pictures) during therapy and over two consecutive data retrievals, as implemented by the Speech and Language Therapist, in a small group setting, without any current achievement, with 80% target achievement
Objective 1.1 Chris will imitate the clinician’s model of a request (verbal, sign, or picture) with prompting as needed during therapy.

Objective 1.2 Chris will appropriately request items, with clinician prompting (verbal, visual, or physical) during therapy.

2. Chris will produce CVC targets (singly syllable words) independently over two consecutive data retrievals, as implemented by the Speech and Language Therapist, in a small group setting, without any current achievement, with 80% target achievement.

Objective 2.1 Chris will produce CV and VC targets given verbal and visual cues.

Objective 2.2 Chris will produce CV and VC targets independently.
Appendix 4

Protocols

Imitation Protocol

1. Clinician successfully performs a gesture (e.g., puts hands up) and reacts with positive emotion (“Up! Hah!”).
2. Robot performs same successful action.
4. Clinician reacts to the robot’s action with positive emotion (“Wow!”).
5. Clinician prompts the child to perform the action (“Now you do it.”).
6. Assistant helps child (hand-over-hand) to perform the same action.
7. Clinician reacts with positive emotion to the child (“You did it!”).
8. Robot reacts positively to the child (light/sound/motion).
9. Sequence is repeated with different gestures.
10. At occasional intervals, clinician attempts actions and fails (puts only one hand up part way).
11. Clinician reacts with negative emotion (“Phooey!”).
12. Robot reacts negatively to the clinician’s failure (sound).
13. At occasional intervals, robot attempts action and fails.
15. Clinician reacts with negative emotion (“Oh, phooey! You didn’t do it!”).
16. Sequence is completed with successful actions.
17. If child is unsuccessful with hand-over-hand action, clinician reacts sympathetically with negative emotion (“Oh, too bad. Sorry.”).
18. The robot also reacts negatively to the child’s failure (sound).

**Give and Take with fruit snacks**

1. Clinician gives a fruit snack to the robot and reacts positively (“Here you go!”)
2. Robot reacts positively (“Thank you” + light)
3. Robot gives a fruit snack to the clinician (“Here you go”)
4. Clinician reacts positively (say or sign “Thank you”)
5. Robot responds (sound, “You’re welcome”)
6. Clinician prompts the child to perform the action (“Now you try”)
7. Assistant helps the child (hand-over-hand) give a fruit snack to the robot.
8. Robot reacts positively (“Thank you” + light)
9. Robot gives a fruit snack to the child (“Here you go.”)
10. Assistant helps the child respond (say or sign “Thank you,”)
11. At occasional intervals, clinician negatively responds to the robot by turning her head away when offered a fruit snack.
12. Robot reacts negatively (sound).
13. If the child is unsuccessful with hand-over-hand action, clinician reacts sympathetically with negative emotion. (“No fruit snack.”)
14. Robot reacts negatively to the child’s failure (sound.)

**Tambourine**

1. Clinician hits the tambourine and reacts positively (“yay!”)
2. Robot reacts positively (sound/light)
3. Clinician positions tambourine under the robot’s arm and prompts it (“Your turn!”)
4. Robot hits the tambourine and reacts positively (sound/light)
5. Clinician reacts positively (“You did it!”)
6. Clinician positions tambourine under the child’s hand and prompts him (“Your turn!”)
7. Assistant helps the child hit the tambourine.
8. Clinician reacts positively (“You did it, too!”)
9. Robot reacts positively (light/sound)
10. At occasional intervals the robot attempts to hit the tambourine and misses
11. The robot responds negatively (light/sound)
12. Clinician reacts with negative emotion (“Oh no! you missed!”)
13. If the child is unsuccessful with hand-over-hand action, clinician reacts sympathetically with negative emotion (“Oh no!” “Too bad.”)
14. Robot also responds negatively (light/sound)
Appendix 5

Classification system of engaged and non-engaged behaviors

**Initiating Engagement**
- Must be spontaneous
  - If the child displays both initiating and responding behaviors in the same 5-second bin, code “Initiating Engagement.” All other behaviors seen are coded under “Initiating Engagement.”

Check YES or NO for each of the following boxes:

- **Does the child use language?**
  - A statement is coded as “language” if it contains a real word or an obvious approximation.
  - The transcript is used to determine if a statement contains a real word.
  - If a word crosses a bin boundary, it is coded in the 1st bin.

  **YES**
  **NO**

- **Does the child display affect?**
  - Affect: laughing, jumping, clapping, or screaming playfully.

  **YES**
  **NO**

- **Does the child imitate?**

  **YES**
  **NO**

- **Does the child make eye contact?**
  - Eye contact is coded if the child is looking upper part of face.
  - Eye contact is coded only if the communicative partner is also making eye contact with the child.

  **YES**
  **NO**

**Responding to Engagement**
- Includes:
  - All closed statements
  - Answers to questions
  - Facilitated requests
  - Responses to comments or actions made by the communicative partner

Check YES or NO for each of the following boxes:

- **Does the child use language?**
  - A statement is coded as “language” if it contains a real word or an obvious approximation.
  - The transcript is used to determine if a statement contains a real word.
  - If a word crosses a bin boundary, it is coded in the 1st bin.

  **YES**
  **NO**

- **Does the child display affect?**
  - Affect: laughing, jumping, clapping, or screaming playfully.

  **YES**
  **NO**

- **Does the child imitate?**

  **YES**
  **NO**

- **Does the child make eye contact?**
  - Eye contact is coded if the child is looking upper part of face.
  - Eye contact is coded only if the communicative partner is also making eye contact with the child.

  **YES**
  **NO**

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**Non-engagement**

Rules:
- Non-engagement periods end when the behavior is no longer seen; NOT when engagement begins again.
  - If non-engagement is seen during a bin, the entire bin is coded as non-engagement.

Check YES or NO for each of the following boxes:

- **Is the child away from the interaction?**
  - Non-engagement is coded if the child is 5 feet or more away from the communicative partner.
  - Non-engagement is coded if the child and the communicative partner are not making eye contact.
  - If the child is no longer considered “away from the interaction” if the CP has joined them.

  **YES**
  **NO**

- **Is the child displaying behaviors of a tantrum?**
  - Tantrum behaviors include crying, screaming, physical aggression, and self-injurious behaviors.

  **YES**
  **NO**

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--Out of the room for any part of the time scan? Non-engagement

--Initiating trumps responding: Put everything in that category

--Upper part of face

--One word that overlaps scan boundaries in initial scan only

--Affect laughing jumping clapping, playful scream

--The child is no longer leaving the interaction once an adult joins him

--we go with transcript to tell us if words are unintelligible (real words, unintelligible, or noises)

--non-engagement is counted if they are not at the interaction, even if they’re returning.

However, not non-engagement if they are away but making eye contact.
--Language must be language, or an obvious approximation

--Initiation if spontaneous, not in response to something I did

--Not eye contact if partner isn’t looking back

--If clinician is within 5 feet of the child, it is NOT coded as non-engagement

--Non-engagement periods end when the behaviors are no longer seen—Not when engagement begins again.

--Response to a comment is responding

--If non-engagement is seen in the scan, it’s ALL non engagement.