Intervention with Children with Autism: The Effect of Using a Robot on Participation in Reciprocal Play

Shereen Ririe
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Intervention with Children with Autism: The Effect of Using a Robot on Participation in Reciprocal Play

Shereen Ririe

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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March 2013

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ABSTRACT

Intervention with Children with Autism: The Effect of Using a Robot on Participation in Reciprocal Play

Shereen Ririe
Department of Communication Disorders, BYU
Master of Science

The current study was part of a larger work investigating the effects of intervention incorporating a robot on the social engagement behaviors of children with autism. The larger study implemented a single-subject, multiple-baseline research design in which four children with autism participated in baseline sessions, traditional intervention, intervention including a robot, and follow-up sessions. The current study focused on the participant’s responses to directives from the clinician and the parent during collaborative activities that included the robot. Children’s responses were analyzed to determine if they responded to directives without assistance, responded with hand-over-hand assistance, or did not comply. Sessions were complex and required the development of a detailed analysis system to ensure fidelity. Overall results were highly variable but showed gains in one child. Clinical observation suggested that all four children benefitted from their exposure to the robot, particularly with regards to regulation. Although variable, the results of this study suggest potential for the promotion and generalization of a child’s ability to respond to social engagement bids with other humans. Additional research should be conducted to establish the effectiveness of a robot in intervention in generalizing social engagement behaviors in children with autism.

Keywords: Autism, Robotics, Joint Attention, TiLar
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Description of Structure and Content

The current thesis is presented in a hybrid format in which current journal publication formatting is blended with traditional thesis requirements. The introductory pages reflect the most up to date university requirements while the thesis content reflects current length and style standards for research published in peer reviewed journals for communication disorders.
**Introduction**

Autism Spectrum Disorders (ASD) have drawn a great deal of attention within the past two decades. Individuals with ASD may exhibit severe deficits in social communication, and a number of intervention approaches have been developed to facilitate basic interactional behaviors. One recent approach that has shown therapeutic promise involves the use of robot technology in intervention activities.

**Autism Spectrum Disorder**

The *Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition (DSM-IV)* (2000) specifies the most widely recognized criteria for autism (Rapin, 1991). This manual is currently under revision and edition V is expected in 2013 (http://www.dsmv5.org). According to the DSM-IV, several disorders are encompassed within the autism spectrum. These include: Autistic Disorder, Rett’s Disorder, Childhood Disintegrative Disorder, Asperger’s Disorder, and Pervasive Developmental Disorder Not Otherwise Specified (American Psychiatry Association, 2000). According to the Center for Disease Control, autism affects 1 in 500 children in the United States and is the third most common developmental disability (http://www.cdc.org/). Other estimates suggest the prevalence is higher (Shamsuddin et al., 2012). Research suggests that the number of children diagnosed with autism is growing, possibly due to increased awareness and standardized diagnostic measures, a genuine increase in number, or a combination of the two (Wing & Potter, 2009).

Autistic disorder, often referred to as autism, is a subcategory of ASD. Autism is characterized by three core deficits in social interaction, communication, and behavioral domains (American Psychiatry Association, 2000; Blackwell, 2001; Shamsuddin et al., 2012). According to Rapin (1991), the lack of reciprocal social interaction with others is the cardinal feature of
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autism. Children with autism do not engage with others in socially appropriate and recognized ways (Campolo et al., 2008; Hughes, 2009). Infants and toddlers may resist cuddling and fail to look up or turn around when their name is called. They struggle with intersubjectivity and intentionality in communication resulting in developmental consequences for establishing relationships later in life (American Psychiatry Association, 2000; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Kasari, Freeman, & Paparella, 2006; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Rapin, 1991; Westby, 1998). These children do not typically engage in imaginative play which can make it difficult to form friendships with other children (Giannopulu & Pradel, 2010; Prizant, Wetherby, Rubin, & Laurent, 2003; Westby, 1980). Other deficits in basic social engagement behaviors include a lack of eye contact, joint attention, emotional and social reciprocity with others, and awareness of other’s presence, needs, and emotions (American Psychiatry Association, 2000; Bruinsma, Koegel, R., & Koegel, L., 2004; Rapin, 1991; Rollins, Wambaq, Dowell, Mathews, & Reese, 2010). Some children with autism exhibit unbridled impulsivity and may be inappropriately affectionate to perfect strangers. Others still may form atypical levels of attachments exclusively with their mothers and react negatively when separated from them (Rapin, 1991). A major treatment goal for children with autism is facilitating meaningful, basic social interaction. Communication in these individuals may be characterized by marked and persistent deficits in both verbal and nonverbal abilities (Blackwell, 2001; Bruinsma et al., 2004; Campolo et al., 2009). In addition to the impact of limitations in expressive language, limitations in receptive language communication may also adversely affect the child’s capacity to maintain a well-regulated behavioral state (Prizant et al., 2003). Individuals with autism may demonstrate restricted, repetitive, and stereotyped patterns of behavior, activities, and interests that are atypical in either focus or intensity (American
Children with Autism and Robots

Psychiatry Association, 2000). These behaviors may include flapping of the hands when excited, rocking, and head banging (American Psychiatry Association, 2000; Campolo et al., 2008; Hughes, 2009; Rapin, 1991). In addition, a diagnosis of autism requires that abnormal functioning be observed before the age of 3 in either of three contexts: social interaction, language as used for social communication, or symbolic play (American Psychiatry Association, 2000; Blackwell, 2001; Rapin, 1991; Robins, Dautenhahn, Boekhorst, & Billiard, 2005). The complete diagnostic criterion for autism is listed in Appendix 1.

Social Engagement

For the purpose of the current study, social engagement is defined as “attending to, expressing interest, and responding to another individual or individuals for the purpose of interpersonal interaction” (Coding Manual, Appendix B). Joint attention is one of the earliest indicators of social engagement (Bruinsma et al., 2004; Kasari et al., 2006; Kasari et al., 2010; Prizant et al., 2003; Westby, 1998). Joint attention involves a “cluster of behaviors that share the common goal of communicating with another person about a third entity in a nonverbal way” (Bruinsma et al., 2004, p. 169). This can be done through eye gaze alteration, pointing, gesturing, showing, and coordinating looks between objects and people (Bruinsma et al., 2004; Kasari et al., 2006; Kasari et al., 2010). It also involves the development of attention states that facilitate mutually sustained joint engagement with others (Kasari et al., 2010).

The capacity for JA facilitates the development of a more sophisticated and explicit system for communication (Bruinsma et al., 2004; Dawson et al., 1998; Hughes, 2009; Kasari et al., 2006; Kasari et al., 2010; Rollins et al., 1998). A child’s ability to monitor the environment through social referencing (i.e. shifting gaze) typically precedes the developmental milestone of intentional communication (Prizant et al., 2003; Van Hecke et al., 2007; Westby, 1980; Westby,
1998). Intentional communication is then followed by an “expanded ability to express intentions across communicative partners and for a range of communicative functions or purposes” (Prizant et al., 2003, p. 300).

Rollins et al. (1998) found that for both typical children and children with autism, a positive correlation exists between joint attention episodes and infant and toddler vocabulary size. Studies have shown that a child’s use of gestures (i.e. eye gaze, pointing) is predictive of their language development for the next year (Rollins et al., 1998). Children with autism have deficient skills in responding to and initiating joint attention which negatively impacts their additional language growth and social engagement abilities (Bruinsma et al., 2004; Dawson et al., 1998; Kasari et al., 2006; Kasari et al., 2010; Prizant et al., 2003; Rollins et al., 1998; Westby, 1998).

In summarizing the literature on joint attention and children with autism, Bruinsma et al. (2004) divided joint attention into two types: responding to joint attention (RJA) and initiating joint attention (IJA). Van Hecke et al. (2007) added an additional type entitled initiating behavior regulation/requests (IBR). Behaviors indicative of the capability for joint attention begin to appear between 3 and 6 months of age. As an infant progresses from the age of 3-18 months, the three types of joint attention emerge and increase in complexity.

RJA is the earliest developing and can take several forms that are functional in responding to the joint attention bids from another person. This includes the ability to follow the direction of gaze, head turn, and possibly a pointing gesture from another person (Van Hecke et al., 2007). RJA plays an important role in the facilitation of increasingly complex interactions. Difficulty in RJA is one of the telling indicators of children with autism (American Psychiatry Association, 2000; Blackwell et al., 2001; Rapin, 1991). IJA involves utilizing eye gaze and/or
deictic gestures (i.e. pointing) in order to spontaneously initiate coordinated attention with another individual (Bruinsma et al., 2004; Van Hecke et al., 2007). IJA is an especially significant prognostic indicator of social and language skills. Studies have shown that better preschool IJA, but not RJA or IBR, skills predicted the development of the tendency to initiate social interactions in children with autism (Van Hecke et al., 2007). IBR may be defined as a protoimperative action which the child initiates attention coordination with another person through the use of eye gaze or gestures in order to elicit aid in obtaining a desired object or event (Van Hecke et al., 2007). In contrast to IJA, IBR may be used less for social objectives, but for more instrumental purposes. For example, if a child takes his mother by the hand and drags her to the sink when he wants a drink, he communicates his needs, but there may be little social connection associated with the request.

**Reciprocal Interaction**

Reciprocal interaction is important because it represents a level of social engagement. In the recent past, much attention has been directed toward establishing intervention practices that address deficits in reciprocal interaction abilities in children with autism. According to Prizant et al. (2003) and Westby (1980), intervention should focus on the development of reciprocal interaction skills (i.e. turn taking) over multiple turns in social exchange and the establishment of a clear intentional signaling system (i.e. respond consistently to a child’s behavior). Other focuses of intervention include the establishment of socially appropriate and conventionalized signals and the increase in variety and frequency of communicative intentions. This should all be done within a context that is both naturalistic and relevant to the child.

Studies that incorporated reciprocal interaction routines and games into their intervention found that gains were made in the joint attention skills of children with autism, particularly in
responding to joint attention (Kasari et al., 2010, Prizant et al., 2003, Rollins et al., 1998). According to Rollins et al. (1998), “the ability to maintain shared attention through social participation in routines precedes true joint attention” (p. 185). Social routines can be used to scaffold language learning and “alert the child to information that should be attended to, and define what can be presupposed” (Rollins et al., 1998, p. 183). Use of early routines has been shown to foster children’s participation in various social interactions.

**Robots in Intervention with Children with ASD**

Recent investigations have described relatively novel approaches that use robot technology to promote social engagement in children with autism. Preliminary investigations show that children with autism can be particularly attentive to robots (Blomgren & Tenggren, n.d.; Dautenhahn, 2003; Diehl, Schmitt, Villano, & Crowell, 2011; Ricks, 2010; Robins et al., 2005). For example, Scassellati (n.d.) compared the behaviors of typical children and children with autism in response to a robot. After the initial novelty, typical children lost interest quickly and preferred to attend to other non-robotic toys in the room. In contrast, children with autism spent almost the entire session attending to the robot, including making eye contact and vocalizing with the robot. These social engagement behaviors were rarely seen and extracted in naturalistic contexts without the presence of the robot.

The Aurora Project was established in 1998 to determine the potential use of robots as a therapeutic tool for children with autism (Goldsmith & LeBlanc, 2004). As part of the Aurora Project, a research study conducted by Dautenhahn (2003) found that children were unafraid of the robot, were motivated to engage with the robot for a period of 10 or more minutes, and were more interested when the robot was in reactive mode compared to rigid, non-interactive
behaviors. The participants in the study did not show signs of distress or behavioral problems when the robot behaved in a way that was reactive but not completely predictable.

Current research suggests that children with autism may respond well to robots as they provide a safe and reliable environment for interaction (Robins et al., 2005). Preliminary research findings suggest that there is potential in the use of a robot and another individual in intervention to facilitate the development of joint attention to objects of shared interest (Diehl et al., 2011). Robots can also be used to provide a predictable and fixed play routine that has a predetermined set of rules and uniformity (Shamsuddin et al., 2012). As the child becomes more confident with the robot, the robot can be designed to adapt over time and generate interactions that are more complex (Blomgren & Tenggren, n.d.; Robins et al., 2005). The use of a robot can simplify the social interaction, allowing the child to focus on the interaction itself as the robot can only communicate in a limited variety of ways. The current focus of research emphasizes the use of a robot that “motivates and engages children, teaches them social skills incrementally, and assists in the transfer of this knowledge to interactions with humans” (Scassellati, n.d., p. 3).

Although many studies have noted that children with autism attend to, and engage with a robot, (Blomgren & Tenggren, n.d.; Dautenhahn, 2003; Goldsmith & LeBlanc, 2004; Robins et al., 2005; Scassellati, n.d.) carry-over of these behaviors in interaction with humans has been limited. Additional research is warranted to investigate the generalization of gains made by children with autism in therapy with robots to real-life situations and interaction with humans.

In 2010, a pilot study was conducted by a team of multi-disciplinary researchers at Brigham Young University to address the issue of generalization of social engagement behaviors in robot intervention with children with ASD (Acerson, 2011; Hansen, 2011; Richey, 2011). Treatment was conducted over a series of 16 treatment sessions with 3 sessions each allocated
for gathering of baseline and follow-up data. A novel characteristic of this approach was the “low-dose” use of the robot during intervention. “Low-dose” refers to the amount of time allocated for the robot to be employed in intervention. The robot was used in highly interactive activities involving the child, a clinician, and often a parent. Another unique aspect of this study was the emphasis placed on affect within the activities.

In the study, each 50-minute session incorporated 10 minutes of robot intervention and the remaining 40 minutes of traditional treatment approaches. The pre- and post-intervention sessions did not include the robot and were analyzed for social engagement behaviors (i.e. eye contact, language, affect, imitation). Results indicated that one child made significant gains while the other participant demonstrated more modest gains (Acerson, 2011; Hansen, 2011; Richey, 2011). Improvements in social engagement behaviors were noted by caregivers and individuals outside of the clinic.

**Purpose**

In 2011, the BYU research team undertook another study to determine if the observed results of the pilot study could be extended with additional participants using a single subject, multiple baseline design. The current study focused on one aspect of the larger project, the social engagement behaviors of four children with autism in reciprocal play sequences including the child, a clinician, a parent, and the robot. Specifically, the purpose of the current investigation was to examine the response of the participants to social engagement bids from both the caregiver and the clinician within reciprocal play routines over a series of 14-17 sessions. The following research question was posed: Did the response to social engagement bids increase in four children with autism throughout intervention utilizing a humanoid robot?
Method

This study was part of a larger project investigating the use of a humanoid robot in a highly interactive, low dose intervention designed to increase the social engagement in children with autism. The following sections describe the four participants, the intervention, the robot technology, and the coding system used to analyze the data. The study was approved by the BYU Institutional Review Board.

Participants

Four children participated in the study. The children were recruited from the Brigham Young University Speech-Language Pathology Clinic waiting list, local preschool and elementary schools, and referrals from professionals on the collaborative team. Each participant had been previously identified with autism through psychological assessment and each exhibited severe, pervasive deficits in social communication. The researchers obtained informed consent and conducted informational interviews with the participants’ caregivers prior to the commencement of the study. The goal of these interviews was to confirm information on clinic intake forms and to gather additional descriptions concerning each child’s social history and present functioning. Each participant underwent a hearing screening at the BYU Speech and Language Clinic. Results from the audiologic examination confirmed that each child exhibited hearing within normal limits. Additional descriptions specific to each participant are provided below.

Participant 1: AH. AH was a 4:11 (year: month) female at the start of the study. She was an only child who lived with both of her parents. She had opportunities to interact with extended family members as well as with children in the developmental preschool she was
enrolled in during the study. Both of her parents were employed outside of the home during the study. English was the primary language spoken in the home.

At the time of the study, AH exhibited marked impairment of receptive and expressive language. She was nonverbal and produced only limited sound play and minimal word approximations. AH could imitate signs immediately following a visual prompt from her mother, but she rarely produced signs to communicate spontaneously. AH usually cried or physically manipulated others without eye contact in order to express her wants and needs. AH demonstrated repetitive motoric patterns with her hands. She had difficulty regulating her behavior, particularly when she was unable to communicate her wants and needs. When behaviorally disregulated, AH would cry and seek tactile support from others (i.e. initiation of a hug with an adult). AH engaged in limited symbolic play. For example, she pretended to feed a doll with a bottle. She also attempted to manipulate the clinicians as if they were dolls. AH rarely established eye contact, shared affect, or attempted to involve the clinicians in a mutually shared experience. The clinicians were rarely able to engage AH in JA activities, reciprocal play or emotional sharing.

Participant 2: LS. LS was a 9:1 year old male who lived with his parents and four older siblings, ages 11, 14, 16, and 18. LS was born in Japan and lived there until he was 4:5. English was the primary language spoken in his home. LS’s father was employed outside the home, and his mother worked within the home as a homemaker. LS had attended a developmental preschool for children with autism, and during the study, he was enrolled in a self-contained classroom for students with autism at his elementary school.

LS demonstrated marked delays in all aspects of social communication. He engaged in sensory stimulation behaviors including tactile stimulation (i.e. being “squished” by a bean bag;
touching different textures in a book) and repetitive motoric patterns. He exhibited poor self-regulation and frequently demonstrated self-injurious behaviors toward himself and aggressive behaviors toward others. At the time of the study, LS’s mother reported that his expressive vocabulary was approximately 150 words. LS sometimes used language to request and protest, but social functions such as showing and commenting were not observed. His verbal communication was restricted to one to two word utterances, extensive echolalia, and requests produced within the “I want ______, please” frame.

Participant 3: KR. KR was 8:1 years old and lived with both parents and five siblings, ages 3, 5, 9, 19, and 23. Her father was employed outside of the home, and her mother worked within the home as a homemaker. English was the primary language spoken in the home. KR had previously attended a developmental preschool specifically designed for children with autism. During the study, KR was enrolled in a self-contained classroom for children with autism.

KR demonstrated severe impairment in social communication. She showed limited verbal abilities characterized by babbling, jargon, and imitation of prosodic patterns. Her expressive vocabulary encompassed four to five real words. KR was often disregulated and threw objects and yelled when upset or frustrated. KR demonstrated behaviors such as hand-biting and visual and tactile fixation on items, seemingly in an attempt to regulate herself. KR showed high levels of physical affection, however, and intermittently established eye contact. KR often smiled and sometimes laughed, but the events that precipitated these displays of affect were often not evident.

Participant 4: LR. LR was a 5:5 male who lived with his parents and five siblings, ages 3, 8, 9, 19, and 23. His father was employed outside of the home, and his mother worked in the
home as a homemaker. English was the primary language spoken in the home. During the study, LR was enrolled in a local developmental preschool specifically designed for children with ASD.

LR also showed marked delays in social communication. He was nonverbal at the commencement of the study and demonstrated sound play with flat prosody. LR displayed repetitive motor patterns including hand flapping and tapping objects together. He attended only briefly to activities initiated by others, and he often left interactions when he became bored or frustrated. LR rarely imitated the actions of others. LR sometimes established eye contact with others and attempted to manipulate others physically. He often displayed positive affect, including laughing and smiling. As with KR, however, the source of LR’s positive affect was not always apparent.

**Robot: Troy**

The humanoid robot, referred to as Troy, was created through the collaborative efforts of graduate students from the Mechanical Engineering and Computer Science departments at Brigham Young University. Troy was a 15-lb upper body humanoid robot that was 63.5 centimeters tall with arms 30.48 centimeters in length: approximately the same size as an average 4-year old child. The body of the robot was comprised of a trunk, base, two arms, neck, and head. Each of his arms had 4 degrees of freedom (DOF): 2 DOF to enable shoulder rotation and elbow flexion/extension and 2 DOF in the shoulder to allow for flexion/extension and adduction/abduction. A 17.78 centimeter computer screen served as Troy’s head and face on which three emotional expressions could be displayed-happy, sad, and neutral (Goodrich et al., 2012; Ricks, 2010).

Basic greetings, songs, rhymes, directions, and both positive and negative affective expressions (i.e. *Yay!*, *Uh-oh!* ) were prerecorded by a BYU student majoring in Music Dance
Theater, thus enabling Troy to perform simple but appropriate verbal responses throughout the session. These prerecorded messages could be projected from a speaker within Troy or from a laptop to which Troy was connected via a USB port. Troy was also programmed with various behaviors that could be employed in reciprocal routines including waving, relevant song motions, tapping with arm, and pushing with an arm. The computer science department at BYU designed a program in which the clinicians used a Wii™ remote to pre-program the robot’s actions, sounds, and facial combinations to be used in the treatment sessions.

**Procedures**

A single-subject multiple baseline design was used for the larger study. Each participant was randomly assigned to receive 3, 4, 5, or 6 baseline sessions to assess levels of social engagement skills (i.e. eye contact, reciprocal turn taking, and language) within three contexts: interaction with an unfamiliar adult, interaction with a familiar adult (the mother) and a triadic interaction involving the clinician, the parent, and the child. Following each child’s participation in the baseline sessions, each participant was seen for intervention for two 50-minute sessions each week. A traditional treatment program was implemented during 40 minutes of these sessions. The robot was incorporated during an additional 10 minutes of intervention. All of the sessions were conducted by four graduate student clinicians at the Brigham Young University Speech and Language Clinic. The Clinic Director of the BYU Speech and Language Clinic supervised the graduate students in order to ensure the quality and fidelity of treatment provided. Concluding the treatment sessions, the activities used in baseline sessions were repeated in order to gather follow-up data for each of the children. For the complete summary of the number of various treatment sessions assigned to each participant, see Table 1.
Table 1

*Number and Type of Sessions Allocated to Each Participant*

<table>
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<tr>
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<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
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<tr>
<td>Baseline</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<tr>
<td>Traditional Treatment</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Traditional Treatment with Robot</td>
<td>17</td>
<td>16</td>
<td>15</td>
<td>14</td>
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<tr>
<td>Follow-Up</td>
<td>3</td>
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**Traditional Intervention sessions.** Traditional treatment sessions were similar to what the child would typically receive at the BYU Speech and Language clinic. These sessions did not include the robot. Sessions were designed to be highly interactive with the participant and consisted of play-based therapy that utilized treatment activities based on the SCERTS model (Prizant et al, 2003). Treatment focused on increasing the participant’s use of intentional communication through verbalization and/or sign, increasing symbolic play skills, and facilitating social engagement with others.

**Treatment Sessions with Troy.** The 10-minute treatment segment involving the robot was randomly placed in the beginning, middle, or end of the entire 50-minute session. The traditional treatment portion of the session was held in a separate clinic room than the robot portion with Troy. The clinicians incorporated Troy into intervention as one on a list of planned activities. Activities were chosen based on their ability to facilitate and elicit social engagement behaviors. The order of presentation of activities varied between the robot sessions and depended on the judgment of the clinician and the interests of each child.
At the appointed time, the clinician would bring the child to the clinic room with Troy, the participant’s parent, and another assisting graduate clinician. The role of the assisting clinician was to provide hand-over-hand support, prompting, and regulation for the participants when necessary. Troy rested on the floor a few feet away from, and directly in front of, the child. The structure of the robot segment included a quadratic interaction between the participant, the participant’s mother, the graduate clinician, and Troy. Intervention focused on using highly interactive activities that emphasized turn-taking and sharing of affect.

Each interaction with the robot began with a series of greetings. The clinician discreetly pushed the appropriate button on the Wii remote that would trigger the robot to greet them. This verbal exchange of greetings was also accompanied by waving. The remainder of the robot segment consisted of group activities targeting turn-taking skills with an object or toy (i.e. ball, music toys, or push car) or singing songs with actions. An example activity would be taking turns pushing a car from one person to another. The clinician would typically model the action for the child and then give a directive similar to “It’s AH’s turn! Push to Mom!” The clinician would then pause to give the child time to perform the action as requested. If the child did not complete the specified action, the facilitating clinician would help the child through hand-over-hand assistance to complete the action. A sample dialog would have been as follows: Clinician: “Push to AH” (clinician pushes car to AH). Clinician: “Push to Mom!” (hand over hand prompt). Clinician and parent: “Yea! Good job!” Clinician: “Mom, push to Troy.” (Mom pushes car to Troy). Clinician: “Yea!” Turns were alternated among the robot, the participant, the clinician, and the mother. The activity would continue until the child became disruptive or bored or a new toy or activity was introduced.
The clinician would purposefully integrate expressions of affect from the robot into the therapy session. An example of this would be Troy failing to complete the desired action (i.e. push a ball) when it was his turn. The clinician would change Troy’s expression from happy to sad and would direct the child’s attention to the change in affect (“Oh, look, Troy is sad. He is sad that he did not get to push the ball!”) The robot was given another turn, (“You can have another try, Troy!”) and performed the action successfully. Again, the robot’s expression was changed and the child’s attention directed to it. The robot segments concluded with each person saying and waving goodbye to Troy.

Data Analysis

All of the sessions were recorded using two video cameras. The first camera was mounted on the walls of the clinic rooms in which the segments took place. This allowed for the entire room and the actions of everyone present to be filmed along with the context of the interaction. This wider angle would facilitate accurate coding of behaviors by capturing the general context in which behaviors occurred. The second was a handheld camera operated by a student volunteer. The purpose of the second camera was to focus on the child’s face. The recordings from the two cameras were synced together using Final Cut Pro Express and facilitated in coding the behaviors of interest.

In the current study, specific activities targeting reciprocal turn-taking and JA skills were conducted to encourage the participant’s interaction with their parent and clinician throughout the robot segments of intervention. An analysis system was developed to identify requests for social engagement (directives) produced by the parent and by the clinician in the context of the turn-taking games conducted. A directive consisted of a verbal request from the clinician or parent for the child to perform an action. These directives were paired with a gesture or model
Children with Autism and Robots (i.e. “Look at me/this” along with pointing to the person or object). Directives were classified into three categories of origination, those produced by the clinician, by the parent, or by parent and clinician simultaneously. Each child’s responses to directives were identified using the analysis system. The child’s response to each directive was labeled as: comply with assistance, comply without assistance, or does not comply. Appendices B and C provide a complete description of the coding manual and checklist as used for the purposes of this study. The robot segments for all four participants were analyzed and coded for the purposes of this study.

**Coding Agreement.** Three graduate student clinicians were trained in the analysis system and inter-judge agreement was established at levels above 80%. One clinician served as the standard and the other two coders established agreement with this clinician. The percentage of agreement established between the two coders and the expert coder is outlined in Table 2. Ten percent of the total robot sessions (six sessions) were coded by all the clinicians for purposes of establishing agreement.

Table 2.  
*Reliability between Other Coders and Expert Coder.*

<table>
<thead>
<tr>
<th></th>
<th>Coder 1 &amp; Expert</th>
<th>Coder 2 &amp; Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td>100%</td>
<td>90%</td>
</tr>
<tr>
<td>Session 2</td>
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<td>100%</td>
</tr>
<tr>
<td>Session 5</td>
<td>87%</td>
<td>91%</td>
</tr>
<tr>
<td>Session 6</td>
<td>93%</td>
<td>88%</td>
</tr>
</tbody>
</table>
Results

The current study examined the responses of the participants to social engagement bids (directives) from the clinician and the mother within reciprocal play routines during a series of 14-17 sessions with the robot. Responses to total directives regardless of speaker will first be presented for each child. Responses to directives from the mother and the clinician are then considered separately as well as bids produced by the clinician and the caregiver at the same time (see Appendix B). The results for each participant are presented in figures below. Tables showing the data from which the figures are generated are provided in Appendix D. Each figure depicts the child’s responses (comply with assistance, comply without assistance, and does not comply) as a percentage of the total directives given. The numbers on the top line in each figure represent the total number of directives given during that specific session.

A line of best fit was inserted for each figure in order to assist in the identification of trends in the performance of each participant. The addition of a regression equation and $R^2$ component were considered, but not included. Two important factors influenced that decision. The first was the fact that a regression equation predicts a linear trend for the data that will continue ad infinitum. This means that any value for treatment episode (X) could be entered to predict a linear response (Y) for the participant. The problem arises because there is typically a ceiling effect in small n designs at which a participant’s responses tend to level off. It is thus impossible to get an ever-increasing therapeutic response. The second reason had to do with the length of time that the intervention took place. Each child participated in 14-17 sessions over a 3-4 month time period. This period of time did not warrant the production of a regression equation that would be helpful in providing an accurate and reliable prediction of response.
AH’s Performance

AH participated in 17 intervention sessions with the robot. Her responses to the total number of directives, her responses to clinician directives, her responses to caregiver directives, and her responses to simultaneous directives during the 10-minute robot segments are provided below.

**Total Directives.** Results for AH’s response to total directives are presented in Figure 1 (and Table D1 in Appendix D).

Figure 1. **AH’s response to total directives represented as a percentage of the total number of directives given for each robot session.**

Results indicate a slight decrease in noncompliance behaviors and in compliance without assistance overall. There was, however, an increase in compliance without assistance and a
corresponding decrease in noncompliance during the first half of intervention with the robot.

AH’s compliance with assistance was variable, but showed an increase across sessions overall. Dips in assisted responses in sessions R8 and R11 should be considered in light of the higher levels of unassisted responses during those sessions.

**Clinician Directives.** Results for AH’s response to clinician directives are presented in Figure 2 (and Table D2 in Appendix D).

![Figure 2. AH’s response to clinician directives represented as a percentage of the total number of clinician directives given for each robot session.](image)

Results showed a slight increase in AH’s appropriate response to a directive with assistance. AH’s responses without assistance saw a sharp rise for the first half of intervention, a decline for the second half, and a slight decline overall. AH’s noncompliance in response to
clinician directives decreased notably for the first half of the treatment program, but then increased toward the end. Overall, noncompliance decreased slightly.

**Caregiver Directives.** AH’s responses to caregiver directives are reported in Figure 3 (and Table D3 in Appendix D).

Results were highly variable across sessions. It is important to note that in many sessions, AH’s mother produced very few directives (0-2). This accounted for some of the wide variability in percentage of response. Overall, compliance without assistance increased, compliance with assistance decreased, and noncompliance was stable.
**Simultaneous Directives.** Results for AH’s response to simultaneous directives are presented in Figure 4 (and Table D4 in Appendix D). In most sessions, very few simultaneous directives were given, and in some cases, no simultaneous requests were presented.

![Figure 4. AH’s response to simultaneous directives represented as a percentage of the total number of simultaneous directives given for each robot session.](image)

Results were variable across sessions. Here again, the percentages of responses were often calculated based on one or two instances of simultaneous directives.

**LS’s Performance**

LS participated in 16 intervention sessions with the robot. His responses to total directives, clinician directives, caregiver directives, and simultaneous directives during the 10-minute robot segments are described below.
**Total Directives.** Results for LS’s response to total directives are presented in Figure 5 (and Table D5 in Appendix D).

![Figure 5](image)

**Figure 5.** LS’s response to total directives represented as a percentage of the total number of directives given for each robot session.

LS’s performance shows relative stability in noncompliant responses with a sharp decrease during R6. Compliance with assistance was relatively stable through the first five sessions, varied in the next five sessions, and was fairly consistent in the final six sessions. Overall, compliance with assistance decreased slightly while compliance without assistance increased slightly.

**Clinician Directives.** Results for LS’s response to clinician directives are presented in Figure 6 (and Table D6 in Appendix D). Figure 6 presents the LS’s response as a percentage of the total directives given.
Figure 6. *LS’s response to clinician directives represented as a percentage of the total number of clinician directives given for each robot session.*

Results showed a slight increase in noncompliant behaviors, with the exception of a dip in session R6. Compliance without assistance increased slightly. Session R11 showed a marked increase. Compliance with assistance decreased somewhat but showed a marked increase during session R6.

**Caregiver Directives.** The results of LS’s response to directives from the caregiver during reciprocal interaction are reported in Figure 7 (and Table D7 in Appendix D).
As indicated in Figure 7, LS’s responses to his mother’s directives were highly variable. For example, in R6, LS responded appropriately without assistance to all directives from his mother. In R1, R13, and R16, he did not comply with any of her directives. Complies with assistance responses were relatively infrequent.

**Simultaneous Directives.** The results of LS’s response to directives from the both the clinician and the caregiver are reported in Figure 8 (and Table D8 in Appendix D). It is important to note that simultaneous directives were limited in number, occurring only 0-3 times for each session.
As indicated by Figure 8, LS’s percentages of response were widely variable across sessions, partly due to the small number of requests.

**KR’s Performance**

KR participated in 15 intervention sessions with the robot. Her response to total directives, clinician directives, caregiver directives, and simultaneous directives during the 10-minute robot segments are described below.

**Total Directives.** Results for KR’s response to total directives are presented in Figure 9 (and Table D9 in Appendix D).
Although KR demonstrated variability from session to session, the results indicate an overall decline in noncompliant behaviors in response to directives. KR’s compliance without assistance increased fairly steadily. Her compliance with assistance decreased slightly.

**Clinician Directives.** Results for KR’s response to clinician directives are presented in Figure 10 (and Table D10 in Appendix D). Figure 10 presents the KR’s responses as a percentage of the total directives given.
Figure 10. KR’s response to clinician directives represented as a percentage of the total number of clinician directives given for each robot session.

Although there was variability from session to session, KR demonstrated a decrease in noncompliant responses to parent directives and an increase in compliant responses without assistance. KR’s responses with assistance were less frequent and decreased slightly across the sessions.

**Caregiver Directives.** The results of KR’s response to social engagement bids from the caregiver during reciprocal interaction are reported in Figure 11 (and Table D11 in Appendix D).
Once again, KR’s performance was variable from session to session. Her noncompliant responses decreased notably in sessions R9 and R15. Compliant responses without assistance varied but increased fairly steadily from R7 through R15. Compliant responses with assistance declined slightly overall.

**Simultaneous Directives.** The results of KR’s response to social engagement bids from both the clinician and the caregiver during reciprocal interaction sessions are reported in Figure 12 (and Table D12 in Appendix D). It is important to note that simultaneous directives were limited in number, occurring for each session at an average between 0-4 times and with a high of eight times in session R1.
Results showed variability in KR’s responses to simultaneous directives from one session to the next. Once again, these results must be considered in light of the fact there were very few simultaneous directives.

**LR’s Performance**

LR participated in 14 intervention sessions with the robot. His responses to total directives, followed by his responses to clinician directives, caregiver directives, and simultaneous directives during the 10-minute robot segments are described below.

**Total Directives.** Results for LR’s response to total directives are presented in Figure 13 (and Table D13 in Appendix D).
LR’s performance showed an increase in noncompliant responses across sessions. His responding without assistance increased slightly across sessions and his compliance to directives with assistance decreased somewhat.

**Clinician Directives.** Results for LR’s response to clinician directives are presented in Figure 14 (and Table D14 in Appendix D). Figure 10 presents LR’s responses as a percentage of the total directives given.
LR’s noncompliant responses increased across sessions. His compliant responses without assistance were variable but decreased slightly overall. Compliant responses with assistance varied but generally decreased slightly.

**Caregiver Directives.** The results of LR’s response to social engagement bids from the caregiver during reciprocal interaction are reported in Figure D15 (and Table 15 in Appendix D).
LR’s performance varied considerably. All of his responses were noncompliant in sessions R5, R6, and R14. With the exception of those sessions, compliant responses without assistance showed increase across sessions. Overall, noncompliant responses increased and compliance with assistance decreased.

**Simultaneous Directives.** The results of LR’s response to social engagement bids from both the clinician and the caregiver during reciprocal interaction are reported in Figure 16 (and Table D16 in Appendix D).
LR’s performance was highly variable throughout the sessions. Some of this variation is due to the varying number of directives. For example, there was only one simultaneous directive in each of sessions R3, R5, and R10.

**Discussion**

There has been much interest generated in recent years regarding the use of robots in intervention programs for children with autism. This interest has been fueled by the fact that although children with autism demonstrate severe deficits in social engagement, turn taking, language, and joint attention skills when interacting with other people, they seem interested in interacting with robots. A number of intervention approaches using robots have been described.
but it has proven problematic to achieve generalization of behaviors to interactions with human conversational partners. The purpose of the larger study was to facilitate social engagement behaviors in four children with autism using an intervention approach involving low-dose exposure to a robot. The robot segment of intervention consisted of various highly interactive activities (e.g., greetings, songs, games, etc.).

The current study focused on the children’s responses to directives given by the clinician and the child’s mother during collaborative activities with the robot. In each session, the robot was situated on the floor a few feet in front of the child. The child’s mother sat on one side of the robot with the clinician on the other. A facilitating clinician sat behind the child to assist the child as necessary. The clinician introduced collaborative activities (i.e. pushing a car) and each person in the group, including the robot, took turns performing the action or activity, as directed by the clinician or the mother. During each activity, affect was emphasized for both positive and negative events ("Yay! Phooey!") Each child’s responses to directives were analyzed. Three categories of response were identified: compliance with hand-over-hand assistance, compliance without assistance (independent response), and noncompliance.

The four participants had low-functioning autism and displayed significant impairment of social engagement and communication. In addition, all of the children had marked difficulty regulating their behavior, and all demonstrated frequent challenging behaviors. All were involved in ongoing treatment and were currently placed in educational programs designed specifically for children with autism. All had specific educational goals, but all continued to show severe impairment over time.

Generally, all four children showed interest in the robot, especially initially. In fact, clinical observation indicated that interacting with the robot helped some of the children regulate
themselves in subsequent activities. For example, AH cried continually during one session until the robot was introduced. She then became calm and remained so even when the robot segment of her session was over.

It was interesting to note that the children did not attempt to interact with the robot without the clinician and parent. The child was more likely to look at the robot, and then look at the parent and smile.

**Evaluation of Results**

Although the four children in the study demonstrated variability in performance from one session to the next, patterns of increase in responses in some areas were evident when considered as a whole. The following discussion focuses on each of the participants and their performance.

**Participant 1: AH.** AH was the youngest and the lowest functioning of the participants. She had difficulty with behavioral regulation as evidenced by extended periods of crying and wailing. Her performance varied and seemed to be influenced by factors such as fatigue. For instance, if she had a full day of school prior to the session, she would be inflexible and prone to crying throughout the session. AH showed initial interest in the robot, and her interest seemed to increase for the first few sessions. During that period, her responses to directives also increased. In subsequent sessions, she seemed to lose interest in the robot, and her responses to directives from her mother and the clinician also decreased. It was observed that AH showed a similar pattern of briefly increasing interest in other treatment activities and materials in intervention time without the robot. In other words, it was challenging for her clinician to maintain AH’s interest and involvement in activities over time. It is important to understand, however, that some of the interactions that occurred in activities with the robot showed a high level of engagement between AH and her mother and clinician. The analysis system used in this study did not fully
capture the richness of the interaction when AH was highly engaged. This level of engagement was not often observed in other settings without the robot. For example, in one session AH fell to the ground, looked at the robot, looked at her mother and clinician to make eye contact, and laughed. This type of emotional sharing was rare. As mentioned earlier, there were instances in which the robot seemed to support AH’s emotional regulation. For example, in one session, AH cried continually until she saw Troy. At that point, she stopped crying, sat down, and participated in collaborative interactions with others, even after the robot was gone.

**Participant 2: LS.** LS was the oldest of the participants. He produced the most language, much of which was echolalic utterances. LS’s difficulties with behavior regulation were extensive and highly variable. For example, when disregulated, LS would pull his clinician’s hair or demonstrate self-injurious behaviors such as biting himself. LS’s performance varied from session to session. LS was interested in the robot and, although it was evident that he enjoyed the sessions, remarkable changes across sessions were not evident.

**Participant 3: KR.** KR’s performance was variable. Her challenges with behavioral regulation were notable. For example, KR often yelled, threw objects, or bit her hand when she seemed frustrated. Out of all of the participants, KR was most likely to try to damage the robot. There were several instances when she hit the robot or thrust the robot’s face backwards with her hand. She would continue this behavior, despite the attempts of the clinician and caregiver to redirect her behavior. Despite her difficulties in regulating her behavior, KR responded well to the collaborative activity with the robot and her independent responses to directives increased across sessions. For KR, the collaborative interactions with the robot elicited some of the most interactive moments of her larger treatment program.
Participant 4: LR. LR’s performance was also highly variable. He also had difficulties with self-regulation, and his behavior was volatile. LR was interested in the robot but remarkable changes were not evident across sessions. The robot seemed to assist LR to regulate himself and maintain a calm demeanor, however. For example, LR frequently ran around the room in intervention, but this behavior decreased notably when the robot was present.

General Observations

In agreement with previous research (Acerson, 2011; Blanchard, 2012; Blomgren & Tenggren, n.d.; Dautenhahn, 2003; Diehl et al., 2011; Dodge, 2012; Giannopolu & Pradel, 2010; Hansen, 2011; Richey, 2011; Ricks, 2010; Robins et al., 2005; Scassellati, n.d.; Shamsuddin et al., 2012; Stabenow, 2012), all of the participants showed interest in the robot. Most of the children maintained interest in the robot over time, with the exception of AH. AH’s initially increasing interest appeared to wane after several sessions. Still, her most interactive moments occurred in the robot activities. It may be the case that intervention could be modified to include brief or occasional exposure to the robot, more varied activities, or new robot capabilities. LS and LR were both interested in Troy, but their response rates to directives remained fairly consistent across sessions. Nevertheless, there were instances in which the robot seemed to support their behavioral regulation as well as their social connection with their mothers and clinicians. For these children, it might be the case that additional time and perhaps expanded activities would be necessary in order to determine the effectiveness of incorporating the robot into intervention.

Of the four children, KR showed the most obvious gains in responding to directives in collaborative activities with Troy. These gains were evident despite KR’s poor behavioral
regulation and her attempts to damage the robot. Intervention that included the robot seemed most promising for this child.

**Study Limitations and Recommendations for Future Research**

The behavior of the children in this study was highly variable. Even though each child had been identified with autism, each presented a unique profile of strengths and challenges. Not only were they different from each other, their behavior differed from session to session and sometimes, from moment to moment. Behavioral regulation was a major factor influencing the results. Each child demonstrated inconsistent levels of regulation across sessions, and this influenced their responses to directives. Behavioral regulation also made it difficult to establish the baseline and follow up measures that were part of the larger study. For example, when disregulated, AH and LR would tantrum and cry, LS would demonstrate self-injuring behaviors, and KR would tantrum, hit, and throw things. When children demonstrated challenging behaviors, it would require additional time and attention in order to help them become regulated once more and resume the activity. Any subsequent research will need to address issues of regulation more directly than was possible in this study. For example, a more extended period of traditional intervention before introducing the robot might be helpful. In addition, an analysis system could be devised that would allow investigators to assess and consider the child’s responses in the context of their current regulatory state. For example, if a child comes in to a session tantruming and upset, the analysis system should account for that.

Even though all of the children showed interest in the robot, its movements were fairly limited. In future research, increased robot capabilities might elicit more interaction from children. For example, it might be particularly helpful if the robot could point to objects at the same time that the head turned to follow the line of regard. In addition, more dynamic robot body
posturing might be used to express emotion (i.e. lean back to express shock, lean forward for emphasis and attention). A wider range of hand movements and manipulation abilities might encourage more reciprocal action as the robot would be able to manipulate a toy or to hand the child or adult an object (i.e. tossing a ball to the child). A mobile robot might approach the child or follow the child’s lead around the room. It might also be helpful for the robot to be programmed with a greater variety of speech. This could enable the robot to be more responsive to the actions of the child. For instance, if the child hit the robot, the robot could respond with “Ouch! That hurts!” It should be remembered, however, that increased robot capabilities should be designed to facilitate interaction between the child and the human conversational partners rather than interaction between the child and the robot.

It is essential to realize that with children with severe deficits in social communication, progress may be slow, subtle, and difficult to document. Analysis systems should be developed to identify and document small gains reliably. In addition, improved recording technology would be helpful. The children’s responses were often intricate and complex, and analysis depended on the quality of the videos used. The child’s face and body were at times obscured by the facilitating clinician during the activities.

The results of this study emphasized the fact that in order to assess whether the intervention is helpful, both the intervention and the analysis must be closely attuned to the needs of each individual child. Further research is needed to learn which children might benefit from intervention including a robot, how long that intervention should extend, and what activities and robot capabilities might be most effective.
**Conclusion**

The current study focused on the way that four children with autism responded to adult directives during collaborative activities that included the robot. Overall results were variable but showed gains in one child. Clinical observation indicated that all four children benefitted from their exposure to the robot, particularly with regards to regulation. Sessions were complex and required the development of a detailed analysis system to ensure fidelity (see Appendix B). There were instances of active engagement from the participants that were not documented by the analysis system. In spite of these limitations, the results of this study suggest potential for the promotion and generalization of a child’s ability to respond to social engagement bids with other humans. Additional research should be conducted to establish the effectiveness of a robot in intervention in generalizing social engagement behaviors in children with autism.


Appendix A

Diagnostic Requirements of Autism (DSM-IV)

A. A total of six (or more) items from (1), (2), and (3), with at least two from (1), and one each from (2) and (3):
   1. Qualitative impairment in social interaction, as manifested by at least two of the following:
      a. marked impairment in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction
      b. failure to develop peer relationships appropriate to developmental level
      c. 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
B. Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years: (1) social interaction, (2) language as used in social communication, or (3) symbolic or imaginative play.
C. The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder.
Appendix B

Coding Manual for Data Analysis

Definitions

1. **Social Engagement**: attending to, expressing interest, and responding to another individual or individuals for the purpose of interpersonal interaction.

2. **Eye contact** = to count must be able to see HEADS and clinician+child in at least one camera. If HEADS are aligned, count it as eye contact.

Rules

1. Read the directions before coding.
2. When in doubt, don’t code.

Games

- Code when the clinician or parent requests that the child perform an action during a game, and pairs that request with a gesture or model. Potential coding possibilities include:
  - Directives from the Clinician – The clinician gives a directive to the child (i.e. “You’re turn,” “give to (name),” “Look at me/this,” etc.). The child may either:
    - Comply with assistance
      - The child performs the action requested by the clinician but requires hand-over-hand support to complete the action.
      - If the child reaches up to the clinician’s hands while the clinician is performing the action, this is considered comply with assistance.
    - Comply without assistance – The child performs the action requested by the clinician on his/her own.
    - Does not comply – The child does not perform the action as requested by the clinician.
  - Directives from the Parent – The parent gives a directive to the child (i.e. “You’re turn,” “give to (name),” “Look at me/this,” etc.). The child may either:
    - Comply with assistance
      - The child performs the action requested by the clinician but requires hand-over-hand support to complete the action.
      - If the child reaches up to the clinician’s or parent’s hands while the clinician is performing the action, this is considered a comply with assistance.
- Comply without assistance – The child performs the action requested by the clinician on his/her own.
- Does not comply – The child does not perform the action as requested by the clinician.
  - Simultaneous Directive – The parent and the clinician give a directive at the same time. The child may either:
    - Comply with assistance
      - The child performs the action requested by the clinician but requires hand-over-hand support to complete the action.
      - If the child reaches up to the clinician’s or parent’s hands while the clinician is performing the action, this is considered a comply with assistance.
    - Comply without assistance - child performs the action requested on his/her own
    - Does not comply – the child does not perform the action as requested by the clinician
Appendix C

Coding Checklist for Data Analysis

GAMES

The clinician or parent requests that the child perform an action during a game.

**Directives from Clinician:**

- **Complies without assistance:** child performs the action requested by the clinician on their own

- **Complies with assistance:** the child performs the action requested by the clinician but requires hand-over-hand support to complete the action

- **Does Not Comply:** the child does not perform the action as requested by the clinician

**Directives from Parent:**

- **Complies without assistance:** the child performs the action requested by the clinician on their own

- **Complies with assistance:** the child requires hand-over-hand support to complete the action

- **Does Not Comply:** the child does not perform the action as requested by the clinician

**Simultaneous Directives:** The clinician and the parent give a directive at the same time.
Complies without assistance: the child performs the action requested on their own

Complies with assistance: The child requires hand-over-hand support to complete the action

Does Not Comply: The child does not perform the action as requested
Appendix D

Data Tables Corresponding to Figures 1 through 12.

Table D1

*Participant 1, AH- Number of Total Directives from the Clinician, Caregiver, and Simultaneous and AH Response Recorded for Each Robot Segment*

<table>
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<th>R14</th>
<th>R15</th>
<th>R16</th>
<th>R17</th>
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<td>Does Not Comply</td>
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</table>

Table D2

*Participant 1, AH- Number of directives from the clinician and AH response recorded for each robot segment*

<table>
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<tr>
<th>Robot Sessions</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
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<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
<th>R13</th>
<th>R14</th>
<th>R15</th>
<th>R16</th>
<th>R17</th>
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</tbody>
</table>
## Table D3

*Participant 1, AH- Number of directives from the caregiver and AH response recorded for each robot segment*

| Robot Sessions | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 | R13 | R14 | R15 | R16 | R17 |
|----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Total Parent Directives | 0 | 4 | 6 | 8 | 6 | 1 | 2 | 0 | 2 | 3 | 3 | 1 | 9 | 6 | 10 | 7 | 1 |
| Comply without assistance | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 3 | 0 | 2 | 4 | 3 | 2 | 0 |
| Comply with assistance | 0 | 2 | 0 | 4 | 3 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 1 | 2 | 0 |
| Does Not Comply | 0 | 2 | 6 | 3 | 3 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 5 | 1 | 6 | 3 | 1 |

## Table D4

*Participant 1, AH- Number of directives from the both the clinician and the caregiver and AH response recorded for each robot segment*

| Robot Sessions | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 | R13 | R14 | R15 | R16 | R17 |
|----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Total Simultaneous Directives | 0 | 0 | 5 | 4 | 1 | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 3 | 2 | 2 | 0 | 1 |
| Comply without assistance | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Comply with assistance | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 0 | 1 |
| Does Not Comply | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
Table D5

*Participant 2, LS- Number of total directives from the clinician, caregiver, and simultaneous and LS response recorded for each robot segment*

<table>
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<tr>
<th>Robot Sessions</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
<th>R13</th>
<th>R14</th>
<th>R15</th>
<th>R16</th>
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<td>34</td>
<td>35</td>
<td>36</td>
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<td>7</td>
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<tr>
<td>Does Not Comply</td>
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</table>

Table D6

*Participant 2, LS- Number of directives from the clinician and LS response recorded for each robot segment*

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<th>R3</th>
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<th>R5</th>
<th>R6</th>
<th>R7</th>
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<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
<th>R13</th>
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</table>
Table D7

*Participant 2, LS- Number of directives from the caregiver and LS response recorded for each robot segment*

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<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
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<th>R12</th>
<th>R13</th>
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Table D8

*Participant 2, LS- Number of directives from the clinician and the caregiver and LS response recorded for each robot segment*

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<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
<th>R13</th>
<th>R14</th>
<th>R15</th>
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<tr>
<td>Comply without assistance</td>
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Table D9

*Participant 3, KR- Number of total directives from the clinician, caregiver, and simultaneous and KR response recorded for each robot segment*

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<th>R6</th>
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<th>R8</th>
<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
<th>R13</th>
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<td>13</td>
<td>13</td>
<td>20</td>
<td>9</td>
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<td>4</td>
<td>7</td>
<td>4</td>
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<td>1</td>
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<td>10</td>
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<td>3</td>
<td>4</td>
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Table D10

*Participant 3, KR- Number of directives from the clinician and KR response recorded for each robot segment*

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<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
<th>R13</th>
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<td>4</td>
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<td>13</td>
<td>10</td>
<td>8</td>
<td>14</td>
<td>7</td>
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<td>11</td>
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</tbody>
</table>
Table D11

*Participant 3, KR- Number of directives from the caregiver and KR response recorded for each robot segment*

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<th>R10</th>
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Table D12

*Participant 3, KR- Number of directives from the clinician and the caregiver and KR response recorded for each robot segment*

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<tr>
<th>Robot Sessions</th>
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<th>R3</th>
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<th>R8</th>
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<th>R10</th>
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<th>R13</th>
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Table D13

*Participant 4, LR- Number of total directives from the clinician, caregiver, and simultaneous and LR response recorded for each robot segment*

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Table D14

*Participant 4, LR- Number of directives from the clinician and LR response recorded for each robot segment*

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Table D15

*Participant 4, LR- Number of directives from the caregiver and LR response recorded for each robot segment*

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Table D16

*Participant 4, LR- Number of directives from the clinician and the caregiver and LR response recorded for each robot segment*

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Appendix E

Annotative Bibliography


Purpose of the study: The purpose of this study was to evaluate the effectiveness of a low-dose intervention procedure utilizing a humanoid robot to increase social engagement in two children with ASD.

Method:
Participants: Two males (ages 3:7 and 7:11) identified with ASD participated in the study. The participants demonstrated severe deficits in social communication and had been enrolled in the Brigham Young University Clinic for traditional speech and language therapy services. Limited gains had been observed in the year prior to the commencement of the study.

Procedure: Pre-treatment data were assessed for baseline levels of social engagement during two 50-minute sessions of interaction. These sessions consisted of child-parent play and child-clinician play assessments. 16 treatment sessions were then conducted over a period of 15 weeks. Intervention was scheduled 50 minutes twice a week. These sessions consisted of forty minutes of traditional speech and language therapy and ten minutes devoted to experimental therapy with the robot. Activities consisted of songs, games, and greetings. After the end of the treatment sessions, post-treatment assessment was then administered in a way that was identical to the pre-treatment assessments.

Results: For child-parent play assessment, the first child showed a decrease in social engagement behaviors (i.e. language, affect, imitation) with the exception of eye contact. The other child showed marked increase in both frequency and duration of social engagement behaviors. Both children exhibited a decrease in the frequency of disruptive behaviors such as tantruming and being away from the interaction. Results from the child-clinician assessment showed that the first child showed an increase in initiating language and eye contact and in responding to affect and eye contact. The second child showed marked improvements in initiating language and eye contact and responding to social engagement behaviors (i.e. language, affect, imitation, and eye contact). The clinicians observed that both children were highly motivated and interested in the robot. Child interactions were observed to improve outside of the clinic sessions.

Relevance to the current study: The current study is an extension of this study.

**Purpose of the work:** The authors integrated results from a comprehensive review of research regarding a range of impairments to define characteristics of each category of impairment in an effort to improve accuracy and standardization of diagnosis.

**Summary:** This volume describes many categories of impairment including Pervasive Developmental Disorders (PDDs). The volume characterizes PDDs as severe impairment in many areas of development such as reciprocal social interaction skills, communication skills, and stereotyped behavior, interests, and activities. Autistic Disorder, Rett’s Disorder, Childhood Disintegrative Disorder, Asperger’s Disorder, and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) are all classified as PDDs. Diagnostic criteria for Autistic Disorder include at least two forms of qualitative impairment in social interaction (i.e. marked impairment in the use of nonverbal behaviors such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction; lack of social or emotional reciprocity; lack of initiation to share enjoyment, pleasure, or achievement), at least one form of qualitative impairment in communication (i.e. delay or absence of spoken language; stereotyped and repetitive use of language, marked ability to initiate or sustain conversation with others; lack of play appropriate for the child’s developmental level), and at least one restricted repetitive and stereotyped pattern of behavior, interests, and activities (i.e. preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus, inflexibility to changes in routines or rituals, stereotyped and repetitive motor mannerisms such as hand flapping, or persistent preoccupation with parts of objects). In addition, a diagnosis of autism includes abnormal functioning in at least one of the following: social interaction, language used for the purpose of social communication, and symbolic or imaginative play. The onset of these manifestations must have an onset prior to three years of age.

Individuals with autism exhibit a range of cognitive and behavioral symptoms that can and must be distinguished from other impairments in order for a diagnosis to be made. The volume discusses the differences that can be found between Autism Disorder and the other disorders of PDDs. For instance, Rett’s disorder is prevalent in females and there is a characteristic pattern of head growth deceleration and the loss of previously acquired hand skills, whereas autism occurs more frequently in males and developmental disabilities are usually noted within the first year of life. The author, in his or her research, made the conclusion that although Schizophrenia may occasionally develop in an individual with a PDD, PDDs are considered distinct from Schizophrenia and other psychoses.

**Relevance to the current work:** This work describes the manifestations associated with a diagnosis of the subtypes of ASD.


**Purpose of the work:** The purpose of this article was to outline a model for the screening and diagnosis of autism.

**Summary:** This article discusses a parameter for screening and diagnosing autism that was developed by a panel of twenty experts on autism. This panel developed a clinical practice
Children with Autism and Robots

guideline (CPG) that distinguishes two levels of analysis that are necessary to make a clinical diagnosis of autism for a child.

The first level, entitled “Routine Developmental Surveillance” involved monitoring a child’s developmental progress and performing a screening in order to identify those children who are at risk for delayed or atypical development (p. 534). The CPG dictates that the screening procedure should be performed “by all providers at every well-child visit” (p.535). Previous studies have shown that “behaviors indicative of CWA [children with autism] are measurable by 18 months of age” (p. 534). These behaviors include deficits in joint attention, orientation to one’s name, pretend play, imitation, nonverbal communication and language development. If a child does not display these behaviors, they should be immediately referred for more in-depth evaluation.

The second level, “Diagnosis and Evaluation of Autism” consists of using clinical guidelines (i.e. DSM-IV) and clinical judgment in order to make a proper diagnosis (p. 536). According to the article, “developmental profiles should focus on the speech, language, verbal and nonverbal communication, and cognitive and sensorimotor deficits” (p. 536). The panel made a list of recommendations regarding the CPG. Some of these recommendations included making time for important parent interviews, observing the child in the context of naturalistic play routines, observe social and communication behaviors, and to reevaluate the child within the first year of the initial diagnosis.

Conclusion: Pediatric healthcare providers need to increase their awareness of autism in order to properly screen and refer at-risk individuals to receive appropriate diagnostic and intervention services.

Relevance to the current work: This article described some of the major characteristics of autism and outlined a plan for screening and diagnosis.


Purpose: The purpose of this study was to examine the social engagement behaviors (eye contact, language, reciprocal action, and initiating interaction) of four children with autism for pre- and post-sessions of robot intervention within the context of a triadic interaction.

Method: Participants: Four children (two males and two females) with autism were included in this study. Diagnosis was obtained through previous psychological and developmental assessments that had been completed at various institutions and clinics, including the Brigham Young University Speech and Language Clinic. All of the participants exhibited severe deficits in social communication as manifested by minimal amounts of joint attention accompanied by severe language impairments.
Procedure: Each child was assigned 3, 4, 5, or 6 baseline sessions. The baseline sessions consisted of a variety of activities targeting social engagement skills. This study focused on the portion of the baseline and follow-up sessions that consisted of a triadic interaction between the child, graduate clinician, and assisting clinician. Four interactive activities, including a ball, car, music toy, and tambourine, were introduced to the child. The graduate clinician initiated the interaction by presenting an object to the assisting graduate clinician. The assisting graduate clinician would then present the object to the child. The child would then be asked to return the object to the graduate clinician. Upon completion of the assigned number of baseline sessions, the child would then complete 20 sessions of treatment consisting of traditional treatment combined with 10-15 minutes of interaction with a humanoid robot. At the conclusion of the 20 treatment sessions, each child participated in three follow-up sessions that were identical in structure and design to the baseline sessions. All of the baseline and follow-up sessions were video recorded for analysis.

Results: All but one of the participants demonstrated an increase in reciprocal interaction (ranging from 11 to 30%). Analysis indicated that three of the four children demonstrated a decrease in eye contact. This may be due to the fact that the simplicity of the robot’s face was not designed to be a motivation for eye contact. Clinical observations did indicate that the children were able to increase appropriate eye contact with others. All of the children demonstrated stability in the areas of language and initiating engagement. Clinical observation indicated that many of the children were able to generalize learned behaviors in intervention to other situations.

Conclusions: Although the results were variable across sessions, this study indicates a promising future for the use of robots in facilitating and generalizing social engagement behaviors in children with autism.

Relevance to the current work: The current study is an extension of this study.


Purpose of the Work: The purpose of this article was to outline the advantages and difficulties in using a robot as an intervention tool with children with autism.

Summary: The authors suggested several reasons for using a robot in therapy with children with autism. First, a robot may be less intimidating and more approachable to a child with autism than an actual human being. Secondly, robots can create a fixed play routine that has a predetermined set of rules and promotes consistency. Finally, robots can simplify the communication interaction as it is limited in its communication abilities, allowing the child to focus on the interaction.

Several details need to be considered when developing the robot. The interface cannot be too bright or detailed, as the child could become distracted from the interaction. The robot must also be flexible and strong enough to withstand reckless handling. It is also crucial to have the ability to manipulate the robot so that the child does not become uninterested or apprehensive. The authors discussed the importance for experts on autism to work closely with the designers of
the robot. This will ensure that the technology will be formed "by and for the context...The technology only exists to fulfill the needs of the individuals" (p. 4).

**Conclusion:** It is important to consider the individual needs and interests of each client when using and developing robots for intervention with children with autism. As this is done, robots may have potential to foster the growth of social behaviors in children with autism.

**Relevance to the Current Work:** This article discusses the use of robots in intervention with children with autism.


**Purpose of the Work:** Bruinsma et al., divided the various definitions of joint attention (JA) into two categories: 1) response to JA (RJA), and 2) initiation of JA (IJA). The researchers defined RJA as the child’s response to the parent’s change in eye gaze whereas IJA was defined as the child’s pursuit of another individual’s attention. This paper focused on IJA forms, including eye gaze alternation, pointing, and showing and IJA functions, such as protoimperatives and protodeclaratives in both typical children and children with autism. The researchers sought to examine the value of IJA as a prognostic indicator of outcome by looking at the relationship between intentional communication and the development of IJA.

**Summary:** The article stated that “emergence of joint attention skills is closely intertwined with the development of intentional communication” in typical children (p. 169). There is no exact instant in a child’s development where communication becomes intentional; rather, the child learns around the ages of 6 to 9 months that “behaviors have consistent and predictable effects” (p. 169). This is done through parent and communicative partner’s attribution of meaning to actions. The article cited Bates (1979) conclusion that intentional communication manifested itself around 9 months of age and consisted of three defining characteristics. Intentional communication characteristics comprised 1) the advent of joint attention, 2) the child’s perseverance in gesturing and/or vocalizing until their communicative goal was achieved, and 3) that the child’s vocalizations during this intentional communication more closely resembled the adult model of speech and/or conventional sounds.

Many researchers agree that the emergence of IJA is critical to the emergence of intentional communication. Instead of a dyadic interaction, the child’s attention is now engaged between their communicative partner and an object. Two main functions of alternating eye gaze include protoimperatives, in which the child requests or rejects a bid for interaction, and protodeclaratives, behaviors such as commenting and referencing along with actions such as pointing and giving.

Children with autism experience deficits in eye contact, a key component of JA. Also, evidence suggests that children with autism do utilize some forms of pointing, although not to the same extent and function as typical developing children. The gestures used in children with autism do not appear to be used as a social reference. When compared with matched controls,
Children with autism requested more, commented less, were more likely to manipulate the examiner’s hand, and were less likely to engage in JA behaviors.

**Conclusions:** One important finding was a strong correlation between the child’s developing lexicon and the time spent in JA episodes. Further evidence suggested a link between JA behaviors and later language development. The study indicated the need for additional research into the importance of precursors to language development. This would allow clinicians insight into developing intervention plans that were individualized to the specific unique needs of children with autism.

**Relevance to the Current Study:** This article discussed the various types of JA and their relation to the development of intentional communication.


**Purpose of the work:** This article serves to present three different types of instruments designed to assess infant behavior in various perceptual and motor domains.

**Summary:** The goal of Neuro-Developmental Engineering (NDE) is to develop novel technologies and approaches for the diagnosis and treatment of neuro-developmental disorders. Three such tools include the instrumented ball, wrist and ankle movement sensors, and audio-visuo-vestibular cap. The instrumented toy was developed to assess grasping skills in infants, the wearable wrist and ankle sensors to measure spontaneous movements of upper and lower limbs in premature babies and the multimodal cap for assessing the orienting behaviors of infants in response to audio and visual stimuli. These devices were designed for application outside of controlled and highly structured environments (i.e. the laboratory) and to be able to monitor the child continuously without being distressful or obstructive.

**Conclusion:** The authors suggest that early diagnosis of neurodevelopmental disorders must be achieved via a multimodal assessment of different perceptual and motor domains rather than one single device, no matter how sophisticated.

**Relevance to the current work:** This work detailed efforts in developing early diagnosis tools for infants and children with autism.


**Purpose of the study:** This article provided evidence from prior research studies in support of the idea that humans form relationships with objects around them, particularly robots. The objective of these researchers in describing three phases of a study, called the Aurora Project, was to determine the prospect and practicability of using interactive, social robots as
therapeutic tools in therapy with children with autism. More specifically, the purpose of the first phase was to verify robots as useful, safe tools in therapy; the purpose of the second phase was to see whether the children behaved differently towards the robot as opposed to a non-interactive toy; and the third phase was done in order to investigate the role of the robot as a social mediator between children with autism.

Method:
Participants: All of the participants in the three phases of the Aurora project were between the ages of 8-12 and included children with autism who were both verbal and nonverbal. 5 children participated in the first phase, 18 children participated in the second phase, and 3 pairs of children participated in the third phase.

Procedures: For the first two phases of the Aurora project, the researchers employed the use of the one-child-one-robot model. This was a framework in which only one participant interacted with the robot at a time. Although no other participants were present, other adults (i.e. experimenters and teachers) were present. The robots were programmed according to a behavior-based design approach in which basic behavioral skills, such as turn-taking and following, were pre-programmed. Robot-human interactions were not predetermined, but instead, were defined according to the robots’ and child’s own actions and interactions. The third phase was structured according to a two-child-one-robot model in which two children interacted with the robot at the same time. The children were paired by teachers according to mutual familiarity and social and communication abilities. Interactions with the robot were unstructured and unconstrained, as the participants were allowed to interact with the robot in any position they preferred (i.e. lying down on the floor, sitting up) and were also free to choose how to interact with the robot (i.e. approaching, picking it up). The researchers only interfered with the robot-human interaction if the participant was about to do something that would damage the robot.

Results: The article mentioned that statistical analyses were performed on micro-behaviors in the human-robot interactions; however, the specific analyses were not identified in this text. A technique known as Conversation Analysis (CA) was also used in order to analyze interactions and communication in more detail and according to context. The first phase of the project provided evidence that the robot was safe to use with children and provided enough motivation for the child to engage with the robot for a period of at least ten minutes. It also showed that the children were unafraid of the robot and were more interested in novel reactions from the robot as opposed to rigid, predictable ones. Results of the second phase showed that most children showed more interest in the robot than a non-interactive toy (i.e. truck) in terms of attention and gaze. The third phase found that the type of interactions demonstrated by the children when they were in the presence of and interacting with the robot reflected their social interactions outside the session.

Conclusions: The author suggested three main findings from the research studies. First, robots need to be able to engage people in social interaction and be programmed with an agenda that will ultimately change the human’s beliefs, attitudes, or behaviors. Second, robots need to be a part of the social environment in order to be truly effective as social mediators. The last conclusion made by the author was that robots can be exploited in therapy as models of social interaction, along with other commercial and engineering possibilities.
Relevance to the current work: This article provides the basic rationale for using robots in intervention with children who have autism. It provides evidence that robots can engage the children in interaction dynamics that are important to the development of social behaviors (i.e. turn taking, eye contact) that could not be done with inanimate toys or objects.


Purpose of the study: This study looked at children with autism and their ability to orient to typical social and nonsocial stimuli that were presented in a naturalistic way. Shared attention skills were also assessed to determine whether there was a relation between the degree of impairment in orientation of social stimuli and shared attention.

Method:
  
  Participants: Three groups of children comprised the participants in this study: 20 children diagnosed with autism or Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS); 19 children diagnosed with Down syndrome, and 20 children exhibiting typical development. The first and third authors of the study independently diagnosed each child in the first group by administering the Childhood Autism Rating Scale (CARS), in which all of the participants scored above 30, and completing a parent interview and structured play session. Autism and PDD-NOS symptoms were diagnosed according to symptoms listed in the DSM-II-R. The three sets of participants were comparable in receptive language mental age as determined by the Preschool Language Scale-3 (PLS-3) and the communication subtest of the Vineland Adaptive Behavior Scales. The first two groups were also matched according to chronological age and verbal IQ.

  Procedures: During testing, each participant was seated at a table across from an examiner that they had interacted with previously. The children were commended for staying seated and were granted breaks as needed. The sessions were videotaped with the focus of the camera on the child’s upper body. There was a smaller video recording that caught the entire context of the room to enable more recognizable and exact delivery of each stimulus. A different examiner was seated in the room and introduced four orienting stimuli. Each lasted 6 seconds and consisted of two social and two nonsocial stimuli. The social stimuli included clapping hands three times and calling the child’s name three times. The nonsocial stimuli included playing a musical toy and shaking a rattle. The four stimuli were presented twice. The first round was presented in the child’s visual range and the second round was presented behind the child. The order of the stimuli was altered between presentations and was distributed between shared attention tasks. The shared attention tasks consisted of two types of probes: the experimenter looked at a toy and pointed to it. Once the child lost interest in the toy, the experimenter took the object and held it near their face. The toy was then removed once the child attended to the experimenter’s face and one of four shared attention probes was delivered. These included pointing to a cross that was in front of the child, pointing at a cross that was behind the child, looking at a cross that was in front of the child and looking at a cross that was behind the child. The sessions were then coded live by two research assistants sitting behind a one-way mirror and
then recoded from the videotape. The coders did not know what the diagnosis was for the participants. Inter-rater percentage agreement was .96 for the orienting tasks and .88 for shared attention tasks.

**Results:** Inferential statistics showed that, compared with typical children and children with Down syndrome, children with autism more frequently failed to orient to all stimuli, but it was most significant with social stimuli. Children with autism exhibited more delayed responses in general, but there was also a more significant occurrence with social stimuli. Statistics also showed that children with autism made significantly more errors in shared attention than the children in the other two groups.

**Conclusion:** This study concluded that children with autism show an overall impairment in orienting ability and shared attention. This impairment is more severe with social stimuli. The children with autism who did orient to the social stimuli were more likely to present a delayed response than the other two groups of participants. One clinical implication of this study was the need to target social attention skills early in intervention.

**Relevance to the current study:** This study demonstrated the need for social attention targets in intervention. Our study has similar procedures regarding video recordings and gaining inter-rater reliability in order to code the sessions.


**Purpose:** The authors presented a review of the literature published in 2010 regarding robots and children with autism.

**Summary:** The review organized the studies into four broad categories: (1) the response of individuals with ASD to robots or robot-like behavior in comparison to human behavior, (2) the use of robots to elicit behaviors, (3) the use of robots to model, teach, and/or practice a skill, and (4) the use of robots to provide feedback on performance.

**Conclusion:** Although isolated studies have shown the use of robots as a promising diagnostic and therapeutic tool in children with autism, the review revealed a lack of uniformity in the methodology, a lack of generalizability of learned behaviors, and other limitations to the studies that have made it difficult to draw firm conclusions about the clinical use of robots in intervention. This review outlined criteria for future studies to follow such as recording detailed characterization of the participants, using established diagnostic techniques in selecting participants, and examining the validity of this technique over other available techniques.

Relevance to the current work: This review provides summaries of articles which described the characteristics of autism and the clinical application of robots in the diagnosis and treatment of autism in children.

**Purpose:** The purpose of the current study was to examine the social engagement behaviors that the children produced in response to bids from an unfamiliar adult.

**Method:**

*Participants:* Four children (two males and two females) with autism were included in this study. Diagnosis was obtained through previous psychological and developmental assessments that had been completed at various institutions and clinics, including the Brigham Young University Speech and Language Clinic. All of the participants exhibited severe deficits in social communication as manifested by minimal amounts of joint attention accompanied by severe language impairments.

*Procedure:* This study employed the use of a single-subject, multiple baseline design. Each participant participated in four types of sessions: baseline, traditional intervention, intervention sessions with a robot, and follow-up. Each participant was randomly allocated to receive 3, 4, 5, or 6 baseline and traditional treatment sessions, followed by 20 sessions of intervention including 10-15 minutes with a robot. Concluding the robot sessions, three follow-up sessions were conducted with each of the participants. Within each baseline and follow-up session, each child participated in four interactions, one with a parent, one with a familiar adult, one with two familiar adults, and one with an unfamiliar adult. This study served to analyze the social engagement behaviors of each child to bids from an unfamiliar adult within the context of the pre- and post- treatment sessions. All of the baseline and follow-up sessions were video recorded and analyzed by the four graduate clinicians conducting the study.

*Results:* Results from individual probes were highly variable, and performance in baseline and follow-up sessions was often inconsistent. Eye contact decreased from pre-intervention measurement to post-intervention measurement in three of the four participants. The language that participants produced in response to probes remained fairly stable across the study. Initiating engagement behaviors decreased or remained relatively stable in three of the four participants. Responding to engagement in the context of symbolic play also remained relatively stable or decreased slightly in three of the four participants. Improvements in responding to bids for turn-taking/singing were observed in three of the four participants.

*Conclusions:* Although the results were variable across sessions, this study indicates a promising future for the use of robots in facilitating and generalizing social engagement behaviors in children with autism.

**Relevance to the current work:** The current study is an extension of this study.

Purpose of the Study: The objective of this study is to investigate the interaction between children with autism and a mobile toy robot during free spontaneous game play. This study is part of the Robautistic project developed in France which focuses on ways a mobile robot can engage children with autism in various interactive activities and spontaneous play.

Method:
Participants: Three boys and one girl participated in the study. Their chronological ages ranged from 7 to 9 years old and their developmental age ranged from 2 to 4 years old. All of the children were diagnosed with autism using the DSMV-IV criteria.

Procedures: Each child participated in one 5 minute session with the robot. An observer was present in the room and a camera recorded the entire interaction for later analysis. As each child walked into the room, the robot would carry out three movements: move forward, move back, and do a complete turn. Robot movement and reaction was standardized across the children. These limited movements included backing away from the child if the child approached and following the child in order to gain attention. Data were analyzed by two independent raters unfamiliar with the purpose of the study. Both used Elan software to complete the analyses of the video sequences. Inter-rater reliability was assessed prior to actual assessment of video data to ensure consistency between raters in their analyses. Four criteria were defined and calculated in terms of seconds: 1) eye contact, 2) touch, 3) manipulation and 4) posture.

Results: Data analysis showed that the participants spent more than 79% of their allocated time engaged in play with the robot. The results of this study are consistent with previous studies that show the use of robots engage children with autism in interaction.

Conclusion: This study encourages the development of longitudinal studies that will promote a better understanding of the influence of robots in intervention on children with autism.

Relevance to the current work: This study showed that spontaneous game play is possible with robots and children with autism.


Purpose of the work: This paper was written to summarize the mounting research in support of the efficacy of using technology-based intervention with children with autism and also to discuss the direction that future research endeavors should take on this subject. Five specific treatment techniques and their efficacy data were discussed.

Summary: Children with autism often need additional prompting and cues in order to regulate behavior. Some widely used prompts include tactile, vocal, and gestural and each method has been shown to be effective. With the advent of technological advances, many types of mechanical prompts have been developed. The two most widely used of these mechanical prompts are auditory and tactile prompts. Auditory prompts have been shown to decrease inappropriate or off-task behavior in children with autism and intellectual disabilities in the classroom and home setting. Two studies have shown that tactile prompting devices promote an
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increase in social initiations of children with autism. One study showed that such devices can be used to assist teenagers with autism in seeking help when they are lost.

Video technology has proven a useful tool in intervention, as it is easily accessible and simple to use. Caregivers and therapists can use video to model appropriate behavior, provide feedback on an interaction, create opportunities for the child to discriminate between appropriate and inappropriate behavior in different settings, all using a mode of technology that many children find appealing. Studies have shown that video modeling as effective tools in increasing conversational speech, social communication, and perception of emotion, among many others. One study compared video modeling to live modeling and found that video modeling was superior to live modeling in terms of rate of acquisition and generalization of skills.

Many studies have been performed on computer-based interventions and children with autism. The results show increasing evidence that they indeed are beneficial in teaching a variety of skills such as improving vocabulary, emotion recognition and prediction, reading and communication skills, and generative spelling. In comparing computer-based interventions with live personal instruction, the results showed similar learning rates, but increased levels of motivation and fewer behavioral issues with computer-based instruction.

The use of virtual environments in children with autism has been limited. Two case studies were performed to assess whether children with autism could stand the equipment and respond in a meaningful way to the virtual world. The participants were able to complete the tasks given to them in the virtual world (i.e. find and walk towards a certain object, identify colors or cars in the virtual street) implying that at least some children with autism may be able to tolerate and interact within these virtual worlds. Another study showed that children with autism were able to increase their attention levels and performance on tasks using these virtual reality interventions.

Robotics is another avenue of intervention that has made its advent in recent years. The few studies that have been done indicate that using robots in intervention can be used to teach basic social interaction skills such as turn taking and imitation and can be used to increase joint attention with family and peers. Robots can create a simplified social environment but can be adapted to increase the complexity of the social interaction.

Conclusions: The author concluded that although technology-based intervention has been shown to be effective treatment methods in children with autism, the next step is to decipher whether they are superior or inferior to traditional, mainstream approaches. The limited evidence that has been gathered on that subject is encouraging. Future research should focus on which design features are critical for producing therapeutic effects and understanding how those features create their impact. Due to the technical complexities of technology, the author addressed the need for clinicians to partner with engineers and programmers in developing appropriate technology for research.

Relevance to current study: This article showed that robot technology can be used in therapy to promote gains in various behaviors such as social interaction skills and increased attention.

**Purpose of the work:** This work describes an interdisciplinary team approach to provide intervention using a robot for children with autism. The paper describes a robot design and user interface that allows speech-language pathologists to use the robot in interactions with a child. The authors then share two case studies that illustrate their approach.

**Summary:** This work described the role of an interdisciplinary team approach in utilizing a humanoid robot for intervention with children with autism. The team outlined included experts from the fields of engineering, mathematics, medicine, and speech-language pathology. Intervention targets should focus on facilitating the child’s response to bids for social engagement and their initiation of social engagement. Due to ethical reasons, robot-based intervention for engaging and eliciting social interactions was set to no more than 20 percent of the total therapy time, a limit referred to as "low-dose".

The robot functions as a part of the larger therapy team and serves to engage the child’s attention and facilitate both dyadic (with child) and triadic (with child, clinician or caregiver) social exchanges. The robot is then phased out of the intervention team in order to encourage dyadic social exchanges between the child and the clinician or caregiver.

In order to fulfill its role on an ASD intervention team, the robot must fulfill two criteria. First, the robot must have an appearance and functions that will serve to engage a child with ASD and facilitate social interactions with other individuals. Second, the robot must be able to execute various social activities (i.e. sing a song and perform related actions, participate in turn taking games, imitate movement). This research team developed a robot that fulfilled these requirements and was able to perform these functions in therapy sessions. Untrained clinicians were able to control the robot and design a therapy program after only 10 minutes of training.

**Conclusions:** Traditional intervention supplemented with low-dose robot-based intervention can promote social engagement in children with autism.

**Relevance to the current work:** The article discussed the potential in using robotics to facilitate social interaction in intervention with children with autism. The current study used the same robot that was described in this article.


**Purpose of the study:** The purpose of this study was to consider the effects of a low-dose intervention program using a humanoid robot on the social engagement behaviors of two children with ASD. The social engagement behaviors of the two children were observed in interaction with an unfamiliar adult and within a triad.
Method:

Participants: Two males (ages 3:7 and 7:11) participated in the study. The participants had been diagnosed with ASD and had been enrolled in special education services. Both children demonstrated severe deficits in social communication, and neither had shown marked growth over the past several months.

Procedure: Pre-treatment measures for triadic interaction and unfamiliar adult interaction were administrated over two 50-minute sessions. Following pre-treatment assessment, each child was seen for intervention for 50 minutes twice a week, for a total of 16 treatment sessions. Each session was composed of 40 minutes of traditional intervention with an additional ten minutes of the session randomly allotted for intervention with the robot. At the conclusion of the treatment sessions, post-treatment assessment was then conducted over two 50-minute sessions. Pre-and post-treatment data regarding triadic interaction and interaction with an unfamiliar adult were then analyzed.

Results: Analysis showed that both participants exhibited an “overall increase in both initiating and responding to engagement” (p. 57). Results were dramatic for the younger child, and moderate for the older child. Improvements in the children’s social exchanges were also observed outside of the clinic.

Conclusions: This study concluded that the highly interactive intervention including low-dose interactions with a humanoid robot facilitated social engagement behaviors in the children with ASD.

Relevance to the current study: The current study is an extension of this study.


Purpose of the work: Hughes presents an overview of research studies published on autism during the year 2008.

Summary: This review provided information regarding topics including, but not limited to, possible parental influences, possible etiologies, vaccines, congenital and neurological disorders, assessment, prevalence, and treatment. The author did not discuss the influence of genes in-depth but suggested that the large amount of research on that subject justified its own review.

Conclusion: Characteristics of autism include repetitive behavior, language disorders, sleep disturbances, social problems, and deficits in joint attention behaviors, among others. It is difficult to narrow down a specific method for diagnosis as a variety of multiple disorders can be present in each child with autism.

Relevance to the current work: This work reviewed articles on the subject of assessment, characteristics, and treatment of autism.

**Purpose of the study:** The researchers sought to examine the efficacy of two targeted interventions of joint attention and symbolic play in children with autism. They also tested for cross-over effects of behaviors to see if there were lower-level effects resulting from the two interventions.

**Method:**

**Participants:** Participants included 58 children ranging in age from 3-4 years who had a clinical diagnosis of autism. All of the children were recruited from an early intervention program. The study reported that the approach of the early intervention program was applied behavior analysis (ABA) and did not include teaching joint attention skills or symbolic play skills. Children were excluded from the study if they had seizures, other medical diagnoses, were 5 years or older or geographically inaccessible. Through randomized selection, 20 children were placed in the joint attention intervention group, 21 children were placed in the play group and 17 children in a control group.

**Procedure:** The researchers acquired permission from parents and guardians through informed consent. Each of the children was then assessed by clinical testers that were not associated with the study and were unaware of the research purpose and goals. Assessments included the ADOS, Mullen Scales of Early Learning, the Reynell Developmental Language Scales, the Early Social-Communication Scales (ESCS), and the Structured Play Assessment. Parents were given the ADI-R and mother-child interactions were observed for 15 minutes during play. In the ESCS, various toys (i.e. wind-up and mechanical toys) were presented to the child and they were given 3 trials to respond. The children were also given 2 trials of a social interaction game (i.e. singing a song followed by tickling). The interactions were videotaped and then scored based on the child’s ability to initiate and respond to joint attention. In the structured play assessment, the child was presented with various toys at a table (i.e. dolls, doll furniture, baby bottles, blocks, telephone). The child’s behavior in response to these toys was recorded and then coded afterwards. The play assessment generally lasted 15-20 minutes. A 15-minute home video recording for each child was also obtained in which the caregivers were told to play with their child as they typically would using a standard set of toys (i.e. blocks, trucks, dishes). The interaction was coded for the child’s play behaviors and types of functional and symbolic acts of play and again for joint attention skills. These assessments were repeated post-treatment to record progress. Each graduate clinician was randomized to treatment procedure and child. The intervention consisted of graduate clinicians working with each child for approximately 30 minutes every day for a total period of 5-6 weeks. A combined approach of behavioral drill and milieu teaching was utilized in the intervention. The child would receive discrete trial training of a particular treatment goal for the first 5 to 8 minutes of the session and then the child would work on the same goal in a child-driven, semi-structured activity on the floor. Goals were deemed mastered if the child initiated the goal in 3 different ways at least 3 times both at the table and on the floor.
Results: Inferential statistics of the ESCS showed that both treatment groups had greater improvement than the control group in initiating shows and coordinated joint looks over time. There was no difference between the joint attention and play treatment group. However, the joint attention group made greater gains in responding to joint attention over time than the control group and play group. Analysis of the mother-child interaction showed that the joint attention group made significant improvement on gives, shows and initiating joint attention than the play and control group. However, both treatments groups made more gains in coordinated joint looks when compared to the control group. Inferential statistics of the play assessment found all groups improved in functional and symbolic types of play; however, the play group improved significantly more than the control group with regards to overall mastered level of play. Analysis of the mother-child interaction showed that children in the play group exhibited significantly more symbolic acts of play and improved their general level of play more than the joint attention and control groups.

Conclusions: The author suggested three main findings from the research study. First, children with autism could be taught joint attention and play skills as evidenced by the improved measurements in structured assessments directed by impartial testers. Second, the children were able to generalize their newly acquired skills from the session room with the clinician to a naturalistic setting with their caregiver. The last conclusion that the author made was that the play and joint attention groups showed some specificity of treatment and similarities in outcomes.

Relevance to the current work: This study provides a rationale for working on skills like joint attention and symbolic play. It supplies evidence that gains in joint attention and symbolic play skills can be made when intervention is focused on those abilities. The assessment process of this study was also similar to our study’s baseline and follow-up procedures.


Purpose of the study: This study aimed to determine if caregiver-mediated sessions would result in greater joint engagement between caregivers and toddlers with autism as well as increased joint attention skills and play diversity. A secondary goal was to examine whether the amount and type of other intervention services and caregiver-rated adherence and competence to participation in the intervention predicted treatment outcomes.

Method:
Participants: Participants included 38 toddlers with autism and their caregivers. The families were recruited through advertisements posted in early intervention sites and local regional centers. The children ranged in age from 21 to 36 months (M=30.82 mo). The average mental age was 19.2 months. Twenty-nine were male and nine were female. Just over 40% of the sample was from ethnic minority backgrounds. 83% of the children were first-born or only children. The caregivers’ average age was 34.5 years and the majority had graduate or professional training.
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Procedure: Nineteen caregiver-child dyads were randomly placed in the waitlist control (WC) group and the other 19 dyads were placed in the immediate treatment (IT) group. The 19 dyads in the IT group participated in follow-up assessments 1 year later. There were no statistically significant differences between the caregivers in the WL and IT groups in pretreatment characteristics such as ethnicity or caregiver’s age and education. Parents were interviewed with the Autism Diagnostic Interview-Revised in order to ensure that their children met the diagnosis for autism. The children were then assessed using the Mullen Scales of Early Learning and the caregiver and child were observed playing with each other for 15 minutes with a standard set of toys. Children in the IT group began an 8-week intervention directly after the initial assessments were completed. Children in the WL group went through a waiting period of 8 weeks. Caregiver-child interaction was once more observed at the end of IT or WL and 12 months after the intervention was completed. The interaction was videotaped and then coded by reviewers that were blind to group status and the point in time being scored (i.e. pre, post or follow-up). The Mullen was administered again at the 12-month follow-up. Caregiver diaries and The Caregiver Quality of Involvement Scale was obtained weekly during the 8-week intervention period for the IT group. Parent comfort level was rated by the interventionist on a 1-5 point scale, with (1) as not comfortable at all, (3) as neutral, and (5) as very comfortable. Parents were also administered a self-report on adherence to implementing learned strategies in the home. Parents were also required to update the various programs and additional therapies that their child was involved in or became involved in throughout the treatment and follow-up period. Joint attention intervention was individualized for each dyad according to the baseline video of the caregiver-child interaction. Each dyad completed the modules in 24 sessions, 3 times a week for 8 weeks. The interventionists were graduate students in educational psychology who had experience working with children with autism. Principles of intervention included following the child’s lead, imitating child’s actions, sitting close to the child and making eye contact, and making adjustments to the environment as needed in order to keep the child engaged. Each dyad received 30 minutes of direct instruction, practice, and feedback from the interventionist.

Results: Inferential statistics showed that children in the IT group engaged in significantly less object-focused play and significantly more joint engagement when compared to the children in the WL group. Children in the IT group showed greater responsiveness to joint attention than the WL group and also exhibited significantly more types of functional play acts than did the WL group. However, the IT group did not show greater initiations of joint attention or increased diversity in symbolic play than the WL group. At the 1-year follow-up, it was found that maintenance occurred for object and joint engagement and gains made in treatment were maintained at the follow-up with regard to responsiveness to joint attention.

Conclusions: The author concluded that caregivers were able to implement intervention with a high level of reliability. Parents were able to help their children improve their response to joint attention, move from engagement centered on objects to increased levels of joint engagement between an item and a person, and increase the diversity of play. However, initiating joint attention may be extremely difficult for children with autism to develop and may also be difficult for parents to teach. In this study, fidelity was not associated with treatment outcome; quality of caregiver involvement, however, was important and did predict child outcome.
**Relevance to the current study:** This study provides a rationale for including parents in intervention with children with autism. It supplies evidence that gains in responding to joint attention and play behaviors can be made with caregiver-mediated intervention.


**Purpose of the work:** The purpose of this article is to provide an overview of the SCERTS model as an approach for facilitating the communicative and socioemotional abilities in children with autism.

**Summary:** When it comes to the treatment for young children, there are a variety of approaches available. These approaches range on a continuum from traditional ABA approaches to family- and child-centered practices. The SCERTS model integrates positive attributes from available approaches and serves to enhance a child’s communication and socioemotional abilities through the use of social communication, emotional regulation, and transactional supports. The SCERTS model was developed over a period of two decades and complies with evidence-based practice principles.

Social communication intervention serves to “enhance capacities for joint attention…and enhance capacities for symbol use” (p. 299). Research has shown that the capacity for symbol use and joint attention are fundamental deficits in children with autism. Emotional regulation “is a core process underlying attention and social engagement and…essential for optimal socioemotional and communication development” (p. 304). An important component of the SCERTS model is an initial assessment of a child’s ability to stay emotionally regulated across contexts and individuals. Plans are then set accordingly to manipulate the environment to provide additional supports for the child to develop self-regulatory and mutual-regulatory strategies.

Transactional support includes 3 major domains: interpersonal support, educational support, and family support. Interpersonal support involves evaluating the various styles of interaction and language use employed by the child’s communication partners and developing strategies to use those specific features (i.e. expression of emotion, use of visual supports) in order to facilitate more successful interactions with others. Educational supports serve to facilitate a child’s learning in a variety of contexts and improve a child’s expressive and receptive language abilities. Family support is given by “providing families with the information, knowledge, and skills to support their child’s development, and emotional support” (p. 311). The outflow of information and resources to the family has been shown to decrease frustration within family relationships. Families can then increase child exposure to treatment strategies by utilizing the strategies in the home within the naturalistic context of important events and daily routines.

**Conclusion:** The SCERTS model can be used to address the core challenges of ASD through the use of social communication, emotional regulation, and transactional supports.
Relevance to the current work: This article described an approach to treating severe communicative and emotional deficits in children with autism.


Purpose of the work: This work provided an overview of causes and characteristics of autism.

Summary: The cause of autism is unknown but some cases may be influenced by a genetic factor (that is also currently unknown). The criteria for diagnosing autism are entirely behavioral and include impairments in reciprocal social interaction, verbal and nonverbal communication and imaginative play, and restricted range of activities and interests, all of which must be manifested at an early age. This article emphasized abnormality in reciprocal social interaction as the cardinal feature of autism. Other characteristics of children with autism were briefly outlined, including the broad range of intelligence, highly labile mood and affect, limitations in attention and arousal, and varied motor deficits. Management of autism is symptomatic; for instance, symptoms of epilepsy and attention deficit disorders are treated the same as with nonautistic children.

Conclusions: Autism is a behaviorally defined developmental disorder of brain function that is attributed to a variety of unknown genetic and nongenetic etiologies. Communication functions, though still limited, tend to improve in all but the most severely impacted children.

Relevance to the current work: This article provided defining characteristics of autism.


Purpose of the work: The purpose of this work was to examine the effect of a humanoid robot as part of a low-dose intervention program on the initiation of social engagement behaviors in two children with ASD.

Method:

Participants: The participants included two males with ASD (aged 3:5 and 7:11). Both participants had been enrolled in traditional speech and language services at Brigham Young University for moderate to severe deficits in social communication. Neither child had shown significant improvement in social communication behaviors in the year prior to the commencement of the study.

Procedure: The participants engaged in two 50-minute sessions of intervention per week. Within each session, approximately forty minutes were devoted to traditional therapy with the remaining ten minutes devoted to intervention with the robot. Sessions were videotaped and stored for later analysis. Analysis focused on the initiating social engagement behaviors of language, affect, eye contact, and imitation.
**Results:** The results showed that each of the participants made gains in initiation of social engagement behaviors within the social context of the robot as well as adults. There was a dramatic increase in eye contact for both of the children with varying improvements in language, affect, and imitation.

**Conclusion:** This study offered three important conclusions. First, each of the participants were interested in and engaged with the robot. Second, the children initiated with both the robot and with the adults. Lastly, both children demonstrated novel behaviors during the intervention process when no gains had been made using traditional methods of treatment.

**Relevance to the current work:** The current study is an extension of this study.


**Purpose:** Ricks discussed the development for and rationale behind a humanoid robot as a therapeutic tool in intervention for children with autism.

**Method:**

**Participants:** The participants in the study included one child with developmental and behavioral handicaps without autism, one child with autism, and two typically developing children. The child with autism was an 8-year-old male demonstrating deficits in social engagement behaviors and joint attention.

**Procedure:** Each child participated in a triadic interaction which included a graduate student clinician, an assisting graduate student clinician, and the robot, named Troy. Troy was an upper-body humanoid robot with two arms, a neck, and a head. The head consisted of an LCD monitor placed in a plastic case. Each arm had four degrees of freedom and the neck had two degrees of freedom. Troy was programmed to display basic facial expressions and actions (i.e. pushing a toy car). Troy was placed in the middle of the room, on the floor, or on a table. The child with autism was given a familiarization stage in order to help the child become accustomed to Troy. After introductions, traditional therapy ensued for 40 minutes. Troy was incorporated into the interaction during the last 10 minutes of the therapy session. The goal of the interaction was to establish engagement between the child and the robot.

**Results:** The typically developing children interacted with both clinician and robot during the session. The child with behavioral and developmental handicaps exhibited positive affect while engaging in the triadic interaction with the robot. The child with autism showed mild interest in the robot throughout the familiarization stage. While interacting with Troy and the clinicians, the child with autism displayed positive affect and was highly motivated to engage in the interaction.

**Conclusions:** Preliminary results showed that the robot could be an tool to facilitate social engagement behaviors in intervention with children with autism. Further research to determine the long-term implications and benefits of using robots in autism therapy was strongly encouraged.
Relevance to the current study: The robot referenced in this article was the same robot used in the current study.


Purpose of the work: This article serves to investigate the potential use of robots as intervention tools with children with autism through the completion and discussion of a longitudinal study. The authors hypothesized that repeated exposure to an interaction humanoid robot would increase basic social interaction skills in the participants.

Method:

Participants: Four children (aged 5-10) with autism participated in the study. All of the children attended the Enhanced Provision unit at Bentfield primary school and were selected by their teacher for participation in the trials.

Procedure: Each child participated in an average of nine trials. The length of each trial depended upon the child and their level of comfort in staying in the room. The average duration of each trial was approximately three minutes, with a few lasting a couple minutes more or less. The trial stopped when the child indicated that he wanted to leave the room or became bored after three minutes had passed. The trials were designed to begin with simple exposure to the robot and progress to facilitate more complex interactions with the robot. Four behavior criteria were evaluated and defined. They included: eye contact (when directed at the robot), touch (when the child touched any area of the robot), imitation (when the child would imitate any of the robot’s movement), and near (the child approaching and staying within close proximity to the robot).

Results: The results from the data showed a considerable increase in the behaviors of interest (eye contact, imitation, touch, and near) in all four of the participants. Qualitative observation also indicated an increase in the child’s social interaction skills with adults in the room.

Conclusions: The results from this study supported the author’s initial hypothesis that repeated exposure to a humanoid robot would increase basic social interaction skills in children with autism. However, it is not clear whether any skills or gains exhibited during the trials would last or if they would generalize to naturalistic contexts.

Relevance to the current study: This study utilized a humanoid robot in order to facilitate social interaction abilities in children with autism and indicated a need for additional longitudinal studies.

**Purpose of this work:** The purpose of this work is three-fold. The authors first discuss shared attention and its influence on other systems of language. They also discuss the developmental sequence of shared attention in typical children. Lastly, the authors identified ways in which this knowledge can shape intervention techniques for preverbal and emerging linguistic children with autism.

**Summary:** The development of shared attention is crucial for infants and children to further their language development. A positive correlation exists between joint attention episodes and infant and toddler vocabulary size. This is the same for children with autism. Studies have shown that a child’s use of gestures (i.e. eye gaze, pointing) is predictive of their language development for the next year. Children with autism differ from typical children in that their development of shared attention is severely truncated. These findings underscore the need for interventionists to engage children in activities that facilitate shared attention.

The development of shared attention follows a trajectory that includes the acquisition of these milestones: 1) understanding others as intentional agents and establishing social intentionality, 2) participating in social routines, and 3) joint attention. Social routines can be used to scaffold language learning and "alert the child to information that should be attended to, and define what can be presupposed” (p. 183). Use of early routines has been shown to foster children’s participation in various social interactions.

**Conclusion:** Increasing functional communication skills is an important intervention goal in children with autism. Shared attention can be facilitated through the use of joint attentional games and routines.

**Relevance to the current work:** The article discusses the importance of shared attention and joint attention routines in developing social engagement skills in children with autism.


**Purpose of the work:** This paper examines the role of social robots in how clinicians diagnose, treat, and comprehend autism and outlines the researcher’s attempts in using such technology as therapeutic aids with individuals with ASD.

**Method:**

**Participants:** A total of 13 children participated in the study, including 7 children with ASD and 6 typically developing children.

**Procedure:** Each of the participants was placed at a table across from a robot, ESRA, for 3-4 minutes. The child’s attentiveness to the robot was observed and compared in two conditions: non-contingent and contingent. In the non-contingent portion, ESRA generated a
variety of facial expressions combined with actions and an accompanying audio file. The robot did not react to any response from the child as it was not programmed to have sensory abilities. In the contingent portion of the experiment, the same behaviors were performed but the timing was controlled by an experimenter sitting behind a one-way mirror. The experimenter would activate the robot as deemed appropriate according to the actions of the child.

Two forms of analyses were performed on the data: passive sensing and interactive social cue measurement. Passive sensing employs the use of vision sensors and a pair of cameras in order to track an individual’s movements within the clinical room, eye gaze, and vocal prosody. Interactive social cue measurements provide information within the context of a social interaction through the use of an interactive robot.

**Results:** The study showed that children with ASD, in contrast to the typically developing children, spent most of the session engaged with and attending to the robot. Children with ASD generated social behaviors directed at the robot including eye contact, vocalizations, and smiling.

**Conclusions:** The robot was effective in engaging and maintaining the attention of children with ASD. This study indicated that additional research is needed to specify the design criteria for a robot to maximize its benefit in intervention.

**Relevance to the current study:** This study discussed different ways in which to analyze data regarding interactions between a child with ASD and a robot.


**Purpose:** This article described a case study in which the initial response and behavior of one child with autism was analyzed when exposed to a humanoid robot named NAO.

**Method:**

**Participants:** The participant in this study was a 10-year-old male with autism. Prior to the study, the participant underwent IQ and diagnostic testing using the Stanford-Binet Intelligence Scale, Fifth Edition and the Autism Diagnostic Observation Schedule.

**Procedure:** The study was held at a NASOM center that catered specifically to youth and children with ASD. The child’s teacher accompanied the child to the session and stayed in the room to be a comforting, familiar presence. 5 modules were executed by the robot NAO in order to elicit reaction and interaction from the child. Two cameras were used to record the child’s initial response and behavior to the robot for each module. If the child became restless or the child’s teacher requested it, the module was aborted. The child was then observed in class for the same duration of time to study his normal behavior among his classmates without the presence of the robot.
**Results:** Observational score sheets regarding the child’s stereotyped behavior, communication, and social interaction in the context of the robot and in the normal classroom were filled out and compared. Results indicated that the child’s single exposure to the robot was able to lessen his autistic traits when compared to his normal behavior in the classroom.

**Conclusions:** The authors concluded that humanoid robots can serve to support and initiate interaction in children with ASD. Additional research was warranted to study the long-term effects of repeated exposure to the same robot in a longitudinal study.

**Relevance to the current study:** This study described the rationale and potential clinical implications of using a robot as an intervention tool for children with autism.


**Purpose:** The purpose of this study was to examine whether an intervention program combining traditional therapy with a humanoid robot would increase the social engagement behaviors (eye contact, language, reciprocal action, and initiating interaction) of four children with autism.

**Method:**

**Participants:** Four children (two males and two females) with autism were included in this study. Diagnosis was obtained through previous psychological and developmental assessments that had been completed at various institutions and clinics, including the Brigham Young University Speech and Language Clinic. All of the participants exhibited severe deficits in social communication as manifested by minimal amounts of joint attention accompanied by severe language impairments.

**Procedure:** A single-subject multiple baseline design was used for the study. All baseline, intervention, and follow-up sessions were administered at the Brigham Young University Speech and Language Clinic. Each participant was randomly assigned to receive 3, 4, 5, or 6 baseline sessions. This study focused on the portion of the baseline and follow-up sessions consisting of interaction with a familiar adult. This included the child interacting with their graduate clinician. This interaction typically lasted for 10 to 15 minutes. The graduate clinician randomly presented the following items to the child: baby doll with blanket, baby doll with food, car, ball, and wind-up toys and sang two songs to the child. Each item and song was presented to the child three separate times. After presenting the object to the child, the graduate clinician waited for 20 seconds to allow the child sufficient time to respond. Following an appropriate response, the clinician would attempt to expand the child’s interaction or would introduce the next object if the response was inappropriate. Concluding each child’s participation in baseline sessions, traditional treatment was implemented. The 20 intervention sessions that followed baseline consisted of traditional intervention combined with approximately 10 minutes of intervention involving the robot. Following intervention, each child participated in three follow-up sessions that were identical in structure and design to the baseline sessions. All of the baseline and follow-up sessions were video recorded for analysis.
Results: Three of the four children demonstrated improvements in reciprocal action. Results indicated that two of the participants showed improvements in eye contact, one showed no change, and the other decreased. Language behaviors and initiating engagement did not change during the probes analyzed for the familiar adult interaction. It was noted that three participants demonstrated small improvement in responding to engagement within the context of symbolic play.

Conclusions: The results from this study are encouraging, but regarded as preliminary. The author encouraged future research to increase the sample size and work to increase the period of traditional intervention and of intervention with the robot, and include a comprehensive analysis system.

Relevance to the current work: The current study is an extension of this study.


Purpose of the study: This article served to investigate the relationship between infant joint attention and social-emotional outcomes in children.

Method:
Participants: 52 infants (34 female, 18 male) were selected to participate from a group of families enrolled in a 9- to 36-month longitudinal study of social development. Inclusion criteria included APGAR scores greater or equal to 7; no history of major medical, sensory, congenital, and/or chromosomal abnormalities at intake; and a 24-month Bayley Mental Development Index score of greater than 75.

Procedure: Parents specified a preferred language (either English or Spanish) for the assessments to be administered at the beginning of the study. Language status and maternal education were assessed when the infants were 9 months of age. At 12 months of age, the infants were assessed for joint attention using the Early Social Communication Scales (ESCS). At 15 months, the infant’s temperament was assessed with a version of the Toddler Behavior Assessment Questionnaire-Revised (TBAQ-R) completed by the parents. Cognitive and language status was tested at age 24 months using the Bayley Scales of Infant Development-Second Edition and the Reynell Developmental Language Scales. At 30 months of age, social-emotional outcome data was examined via parent endorsements on the Infant-Toddler Social and Emotional Assessment questionnaire (ITSEA).

Results: Inferential statistics of ESCS scores showed significant associations between initiation of joint attention (IJA) and high-level initiation of joint attention (Hi-IJA) and also between initiation of behavior requests and response to joint attention. The 12-month JA measures displayed a significant pattern of associations with 24-month language and cognitive measures. There was a significant association between higher 12-month IJA scores and lower
parent report of Externalizing behavior in the ITSEA and also between higher Hi-IJA scores at 12 months with higher Social Competence scores at 30 months.

Conclusion: Infants display a range of individual differences in the development of JA skills. These differences are associated with variability in preschool social competence, as well as cognitive and language outcomes. This article emphasized the need for additional information regarding the nature of processes that give rise to these individual differences in ability.

Relevance to the current study: This article discusses the relationship between joint attention skills and the development of social-emotional outcomes in children.


Purpose of the work: This article presents a symbolic-play language scale and describes the 10 stages in the development of symbolic play abilities with related language concepts and structures. The role of this scale in evaluation and intervention planning is also outlined.

Summary: The symbolic play scale developed from a program based on Piaget’s theory of cognitive development. In this theory, Piaget divided cognitive development into four major stages. The major cognitive development during the preoperational period (18 months to 5-7 years) is the development of representational thought. "Symbolic play provides a means of assessing children’s representational abilities" and is a precursor for meaningful communication (p. 155). The various stages in the symbolic play scale range from developing object permanence and means-end abilities to representational play with self and others and progress in complexity until the final stage where the child can predict future events and plan out pretend sequences in advance.

Two purposes for the symbolic play assessment were given. The first was to determine if a child should be given priority for receiving language intervention, and if so, which communicative functions, semantic concepts, and syntactic structures should be taught. This study emphasized that “unless the child possesses the cognitive prerequisites for the linguistic structures she/he is learning, she/he will not use them in actual interpersonal situation” (p. 162). Intervention should begin at the child’s current language level and then follow the developmental sequence to develop necessary language skills.

Conclusion: Structured language sessions should not be the primary focus of intervention in children with delayed language abilities. This article cited a study showing that adult-directed intervention actually impedes progress. Instead, the clinician should utilize naturalistic, interactive play activities in order to assess a child’s language skills and provide a context in which to provide intervention.

Relevance to the current study: This study outlines the function of symbolic play in assessment and its importance in the development of meaningful communication.

Purpose of this work: Westby discussed the various affective and social bases of communication and the development of intentionality in communication. She also presented information regarding factors that affect the social and emotional bases of language and methods to assess and facilitate the development of these crucial underpinnings for communicative competence.

Summary: Westby introduces the chapter by stating that “intentionality drives language acquisition and intersubjectivity drives intentionality” (p. 168). Language learning and the emotional state of a child are connected as infants learn to talk about the causes, circumstances, and objects of their emotion. This understanding is then extended to an awareness of other people’s thoughts, feelings, and emotions. This” interfacing of minds with other persons” (p. 168) has been deemed the term theory of mind (TOM). Intersubjectivity is dependent on a child’s ability to establish joint attention with others. Once an infant has established joint attention, they now use behaviors intentionally to obtain the adult’s attention.

Westby discussed various assessment options to use in the assessment of social and emotional bases for communication. These included: naturalistic observation, caregiver-child interactions, interviews, and standardized tests. Clinicians should observe and evaluate a child’s ability to recognize and interpret the emotions and beliefs of another individual and the child’s understanding of TOM concepts (i.e. joint attention, implicit false-belief tasks). Intervention should focus on the development of reciprocal interaction skills (i.e. turn taking), establishment of a clear intentional signaling system (i.e. respond consistently to a child’s behavior) and socially appropriate and conventionalized signals, and increase of the variety and frequency of communicative intentions.

Conclusions: This chapter emphasized the importance of intervention goals that target emerging social and communicative abilities to establish TOM and facilitate intentionality in communication. Joint attention is an essential component for the development of TOM.

Relevance to the current work: This chapter presented the various affective and social underpinnings for the development of communicative abilities and the importance of joint attention and TOM in developing intentionality in communication.


Purpose of the work: The purpose of this article is to discuss whether there is a genuine rise in the incidence and prevalence rates of autism or if it could be explained by the general increase in awareness and diagnostic measures available.

Summary: When it was first discussed by Leo Kanner in 1943, autism was considered to be a rare disorder occurring in 2-4 per 10,000 children. Studies performed from 1966 until 2000 have shown a general increase in prevalence from the original estimate. The authors outlined several
potential reasons for the increase in autism. These reasons included: modification of diagnostic criteria, the variety of methods used in the studies, increasing awareness in caregivers, professionals, and the general public, recognition that autism can co-occur with other physical and developmental impairments, the development of specialist services, possible causes and relation to age of onset, and a possible authentic increase in numbers. The article stressed that the contribution of each of these factors is unknown. For instance, the results from twin studies strongly suggest that genetic factors are a major component in the etiology of over 90% of children diagnosed with autism using the DSM-IV. However, genetic factors alone are unlikely to account for the real rise in rates. In discussing the possibility that rates of autism have truly risen, many factors were discussed. These included environmental factors, medical conditions, and the MMR vaccine.

Conclusions: The authors concluded that the reported rise in incidence and prevalence of autism is due in large part to changes in diagnostic criteria and greater awareness among caregivers and professionals. It is still unclear whether a genuine rise in the number of children with autism exists and, if so, the degree of increase and whether the numbers will continue to rise.

Relevance to the current work: The article discussed the increased incidence and prevalence of children with autism. This article validates the current study’s goal in developing additional intervention techniques to improve the social and communicative abilities in the potential growth in the number of these individuals.