The Effects of Utilizing a Robot on the Social Engagement Behaviors of Children with Autism in a Triadic Interaction

Kristi Anne Blanchard
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The Effects of Utilizing a Robot on the Social Engagement Behaviors of Children with Autism in a Triadic Interaction

Kristi A. Blanchard

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

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ABSTRACT

The Effects of Utilizing a Robot on the Social Engagement Behaviors of Children with Autism in a Triadic Interaction

Kristi Blanchard
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Master of Science

The study presents the use of a humanoid robot to facilitate social engagement behaviors in four children with autism. These children were enrolled in a semester long treatment program based on components of the SCERTS model designed to facilitate social communication (Prizant, 2003). Following baseline, children received intervention sessions with and without the robot. During sessions involving the robot, each child would participate in a 10 minute interaction (as part of a 50 minute session) using a robot to facilitate interaction with a graduate clinician or parent. The interactions were recorded and analyzed for occurrences of social engagement behaviors. This study focused specifically on the triadic interaction that occurred in the pre-and post-intervention sessions. The triadic interaction was a structured play sequence involving three individuals (the child, the graduate clinician, and the assisting graduate clinician). The results suggest that the robot has potential to facilitate reciprocal action between children with autism and adults.

Keywords: autism, robot, social engagement
I would like to express my gratitude to Dr. Fujiki, Dr. Brinton and Dr. Goodrich for their guidance and support throughout this project. I would also like to thank Alyssa Stabenow, Cambrie Roueche, and Sarai Dodge for being wonderful research partners and incredible friends. I have learned so much from them about being a clinician and being an overall better person. I will forever be indebted to them for the lessons I have learned during this experience. I also could not have done this without our cohort. Again, these people have changed my life and I can’t express my gratitude for the things I have learned from them. I will carry their bag of tricks for surviving life with me for the rest of my life. Lastly, I would like to thank my family for their support and encouragement during this process as well as during my graduate studies.
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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. Appendix A is composed of an annotated bibliography. Appendix B provides an outline of the baseline and follow-up measures. Appendix C includes the coding manual used for the data analysis.
Robots and Children with Autism

Introduction

Autism is a developmental disability that typically results in impairments in social engagement behaviors, particularly social interaction and joint attention skills. Intervention for children with autism primarily focuses on establishing and expanding these social deficits in natural contexts. A relatively new approach to autism intervention which is currently being researched is the use of robots within treatment sessions to facilitate the growth of social engagement behaviors.

Nature of Autism Spectrum Disorder

Autism Spectrum Disorders (ASD) are characterized by severe and pervasive impairments in several areas of development (American Psychiatric Association, 1994; Prelock & Contompasis, 2006). According to the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition (2000), ASD encompasses the following disorders: Autistic Disorder, Rett’s Disorder, Asperger’s Disorder, Childhood Disintegrative Disorder, and Pervasive Developmental Disorder Not Otherwise Specified (American Psychiatric Association, 2000). Of these disorders, Autistic Disorder or autism is the third most common developmental disability and affects between 60,000 to 115,000 children within the United States (Blackwell, 2001). Autism is defined on the basis of deficits in three areas: “social interaction, communication and play, and restricted patterns of interest” (Volkmar & Klin, 2000, p. 1725).

Deficits in social development form the core of autism. Siebert, Hogan, and Mundy (1982) discuss three key components of social development that are impacted: “social interaction, joint attention, and behavior regulation” (p. 248). Similarly, Mundy and Sigman (2006) indicated that the overall goal of social development is for the child to interact successfully with their environment in appropriate prosocial ways. To do this, a child must be
able to regulate attention in a social interaction, self-monitor and adjust social behaviors, and demonstrate positive emotions and interest toward others (Mundy & Sigman, 2006). The lack of social development, primarily the appearance of effective social interaction and joint attention, is often thought to be critical in the overall difficulty children with autism have in establishing meaningful social relationships.

Social Interaction and Joint Attention

A key component of social development is the establishment of effective social engagement through joint attention (JA). For the purposes of the current study, social engagement includes “attending to, expressing interest and responding to another individual or individuals for the purpose of interpersonal interaction” (TiLAR Team, 2012, p. 1). Children with autism may experience a lack of social engagement due to limitations in establishing JA.

JA is a foundational milestone of a child’s social development (Siebert et al., 1982). The importance of JA lies in its role in the development of theory of mind, or the child’s ability to “understand others’ thoughts, intentions, and feelings” which is essential for successful socialization (Westby, 2010, p.137). JA is defined as a “cluster of behaviors that share the common goal of communicating with another person about a third entity in a nonverbal way, including eye gaze alternation and gesturing” (Bruinsma, Koegel & Koegel, 2004, p. 170). Prelock (2006) expands on the previous definition to include the use of “verbal communication such as labeling and commenting to direct another’s attention to or share interest in objects or events” (p. 256). The overall goal of JA is to establish the ability to share an experience with another person.

Westby (2010) divides JA into three different categories: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). During the 3-18
month period of infancy, the three types of JA develop and increase in complexity. RJA develops initially and is characterized by the ability to follow a communicative partner’s eye gaze, head turn, and/or gestures toward a specific object or event (Westby, 2010). IJA is more refined because of the increased conscious awareness needed for the infant to use eye contact and gestures to initiate the attention of another person to elicit aid in obtaining an object or event. RJA and IJA are important due to their predictive role in developing later language and effective social functioning. Deficits in the ability to establish these types of JA correlate with the lack of social engagement seen in children with autism (Bruinsma et al., 2004; Kasari, Freeman, & Paparella, 2006; Westby, 2010).

**Triadic Interaction**

During typical development, there is a shift from dyadic person-person interaction to a triadic person-person-person interaction. The ability to engage in a triadic interaction with people typically develops “late in[to] the first year” after infants have developed basic joint attention skills (Tremblay & Robira, 2006, p. 367). Children with autism are known to have difficulties developing joint attention; therefore, their ability to be successful in triadic interactions is limited. Some researchers have concluded that the difficulty children with autism have in triadic interactions is based primarily on the inability to develop effective social interaction skills in a dyadic context. Carpendale and Lewis (2004) highlight the importance of triadic interaction in the development of greater social understanding and knowledge of the world as well as knowledge of other people. More importantly, the framework of a triadic interaction allows an increase of opportunity for the child to engage in a cooperative social interaction (Carpendale & Lewis, 2004).
In the past decade, intervention programs for children with autism have established an increased focus on social skills (Scattone, 2007). Social skills intervention has evolved from targeting simple behaviors such as attention and eye contact to include activities based on “play, perspective taking, and conversation skills” in a natural context (Scattone, 2007, p. 717). With an increased focus on social skills in intervention, triadic interactions have been suggested as a framework that could facilitate greater joint attention and overall social engagement (Goodrich, Colton, Brinton & Fujiki, 2011). Because of the nature of triadic interactions, they may provide an important context in which to focus on increasing social engagement behaviors.

**Establishment of Social Engagement with a Robot**

A relatively new approach to autism intervention is the use of robots as a therapy tool to facilitate the expansion of social engagement behaviors. Children with autism show a heightened interest in technological devices, particularly robots (Goldsmith & LeBlanc, 2004). Scassellati (n.d) compared the interactions of typical children to those of children with autism in the presence of a robot. The typical children exhibited initial interest in the robot but showed overall preference to the other non-robotic toys present in the room. The children with autism spent a majority of the session “attending to the robot, regardless of whether or not it was responding contingently to them” (Scassellati, n.d., p. 4). It is of note that while in the presence of the robot the children with autism generated behavior that was “similar to their typically developing peers, including smiling at the robot, making eye contact, and vocalizing to the robot” (Scassellati, n.d., p. 4).

Some researchers suggest that children with autism show a heightened level of interest in interacting with robots because they are safe, inanimate objects that provide an enjoyable and relaxing interaction for the child (Miyamoto, Lee, Fujii, & Okada, 2005). Studies have also
suggested that the robot generates an increase in motivation and engagement in children with autism. The robot provides a “simplified social environment” and can increase the complexity of the social interaction to fit the needs of the child (Goldsmith & LeBlanc, 2004, p. 172). Due to the interest of children with autism in robots, robots have been suggested as a potential intervention tool. Robots may be able to provide a means to teach social interaction skills by providing opportunities for the child to turn-take, imitate games, and be the focus of shared attention to encourage interaction with others. Current research indicates that robots facilitate improvements in the social engagement of children with autism; however, the ability to generalize those social engagement improvements to interactions with people without the presence of the robot has rarely been documented.

In 2010, a team of researchers at Brigham Young University conducted a pilot study investigating the efficacy of utilizing a robot in a 15-week treatment program with two children with ASD (Acerson, 2011; Goodrich et al., 2011; Hansen, 2011; Richey, 2011). The social engagement behaviors from the pre- and post-treatment sessions without the robot determined that “one child showed a dramatic increase in social engagement behaviors and the second child showed modest gains” (Richey, 2011, p. 5). In 2011, the study was expanded to include four children with autism and to continue to explore the use of robots to facilitate social engagement in a triadic interaction. The present study examined social engagement behaviors of the four children across the pre- and post- sessions of robot intervention. The behaviors that were analyzed in the triadic context included eye contact, reciprocal action, language, and initiating interaction. This study addressed the following questions:

1. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing eye contact in a triadic interaction?
2. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing reciprocal action in a triadic interaction?

3. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing language in a triadic interaction?

4. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing initiating interaction behaviors in a triadic interaction?
Method

This investigation is one aspect of a larger project in which four children with autism were studied to determine the value of using a robot in intervention to facilitate social engagement. The following is a description of the participants and intervention methods employed.

Participants

The participants included four children (three males and one female) with autism. Each of the children exhibited severe deficits in social communication including minimal amounts of joint attention and severe language impairments. The children were identified with autism by previous psychological and developmental assessments completed at various local institutions and clinics. Informed consent was provided by each of the participant’s parents prior to the study. Further assessment was completed at the Brigham Young University Speech and Language Clinic by graduate clinicians. The results from each individual assessment assisted in establishing treatment plans and goals for each child. Demographic data as well as the results of observation and individual assessments are summarized for each child as follows.

LR. LR was a 5:5 (year: month) old male. He lived with both of his parents as well as his 5 siblings (ages 3, 8, 9, 19, and 23-years-old). His father was employed and his mother worked in the home as a homemaker. English was the primary language spoken in the home. At the time of the study, LR attended a specialty school for children diagnosed with autism. The following information was obtained from parent report and direct observation in the clinic during formal and informal assessment.

LR demonstrated high levels of repetitive behaviors such as flapping his arms and tapping items together. LR was nonverbal at the time of the study but did exhibit non-variegated
sound play. On occasion, LR would use gestures to communicate but would predominately initiate interactions by eliciting aid from another person to obtain a toy or item. He showed very limited attention to social interactions and required maximal support to participate in simple reciprocal play activities. LR did show moderate levels of eye contact associated with positive affect during social interactions.

**KR.** KR was an 8:1-old-female. KR lived with both of her parents and her 5 siblings (ages 3, 5, 9, 19, and 23-years-old). Her father was employed and her mother worked in the home as a home maker. English was the primary language spoken at home. Prior to the study, KR attended a developmental preschool for children with autism, but at the time of the study, she was enrolled in a self-contained autism unit at an elementary school. The following information was obtained from parent report and direct observation in the clinic during formal and informal assessment.

Socially, KR demonstrated limited communication skills. She babbled or verbalized using jargon but had only approximately 4-5 words. She made moderate attempts to initiate engagement by establishing eye contact associated with positive affect. At times, the eye contact and affect were associated with vocalizations. KR did not always respect physical boundaries between herself and others. For example, she frequently attempted to sit on, lie on, or hug the clinicians. KR demonstrated frustration by yelling or throwing items when her communicative partner misinterpreted her desired communicative intent. Also, when frustrated, KR would self-regulate using behaviors such as biting her hand or sensory stimulation behaviors with specific toys or items.

**LS.** LS was a 9:1-old-male. LS lived with both of his parents as well as his 5 siblings (ages 11, 14, 16 and 18-years-old). LS was born in Japan and lived there with his family until the
age of 4:5 years. His father was employed and his mother worked in the home as a homemaker. English was the primary language spoken in the home. Upon moving to the United States, LS began schooling at an autism preschool and then later was enrolled in a specialty kindergarten for children diagnosed with autism. The following information was obtained from parent report and direct observation in the clinic during formal and informal assessment.

At the time of the study, LS was verbally communicative with an estimated 150 word lexicon. He exhibited limited intentional communication, relying on basic word combinations such as “I want ____” to request a desired item. LS frequently produced echolalic utterances, but the communicative intent of these utterances was unclear. LS showed impairments in emotional regulation and often became over stimulated by environmental stimuli. When he was dis-regulated, LS exhibited self-injurious behaviors or aggression towards others. On occasion, LS demonstrated appropriate reciprocal action in social interactions but showed limited engagement in the activity.

AH. AH was 4:11-old-female who lived with both of her parents. Both of her parents were employed and the primary language of the home was English. At the time of the study, AH attended a developmental preschool for children diagnosed with autism. The following information was obtained from parent report and direct observation in the clinic during formal and informal assessment.

AH was typically nonverbal but she produced minimal verbal approximations and inconsistent sound play. She produced some signs but usually required a visual prompt to produce signs that were appropriate to the context. She showed limited initiation of social interaction. However, she did elicit aid from an individual to gain an object or toy by leading someone by the hand. AH demonstrated basic symbolic play skills with select objects, such as
feeding a baby doll with a bottle. In addition, she occasionally attempted to manipulate people by pushing two clinicians together to hug one another. She manifested difficulties regulating emotions and frequently cried to express dissatisfaction or frustration.

**The Robot: Troy**

The humanoid robot used in the study was created by a team of graduate students from Brigham Young University in the Mechanical Engineering and Computer Science Departments. The robot, referred to as Troy, was designed as a 15-lb upper-body robot that would be the similar size to a 3–4 year old child. Troy was designed to include a base, trunk, 2 arms, neck, and head (Ricks, 2010). He was approximately 24 inches (63.5 cm) tall with arms approximately 12 inches (30.5 cm) in length. The robot’s face was a 7-inch (17.8 cm) computer screen that could be programmed with simple faces such as happy, sad, or neutral (Goodrich et al., 2011). A speaker was attached to the torso which allowed speaking and singing capabilities. Troy was connected to a computer for programming purposes and was controlled by clinicians through the use of a Wii™ remote. His design was focused on “promoting turn-taking and imitation behaviors” (Goodrich et al., 2011, p. 144). Therefore, he was programmed to produce basic vocalizations and movements of the arms and neck to facilitate reciprocal interactions. For further information see Ricks (2010), Acerson (2010), Hansen (2010).

**Procedures**

The current study is part of a larger investigation which utilized a single subject multiple baseline design. Each child was assigned a staggered number of 3, 4, 5, or 6 baseline sessions. At the conclusion of the baseline sessions, each child participated in 20 treatment sessions. The 20 treatment sessions were composed of 50-minute traditional treatment sessions and 40-minute traditional treatment sessions accompanied by a 10-15 minute interactions with a humanoid
Robots and Children with Autism

Table 1 presents a summary of the organization of treatment sessions assigned to each child. Each child was paired with a primary graduate clinician who was responsible for providing therapy during portions of the baseline and follow-up as well as the 20 sessions of treatment. An assisting graduate clinician was also assigned to the child for the entirety of the study. The assisting graduate clinician provided additional support during the triadic interactions during the sessions of baseline, follow-up, and the 10-15 minutes interaction with the humanoid robot. The focus of the current investigation was on only the baseline and follow-up sessions.

Table 1

*Number of Sessions Assigned to Each Participant*

<table>
<thead>
<tr>
<th></th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<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>
</tr>
<tr>
<td>Follow-Up</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Baseline and follow-up.** Initially each participant was involved in a varying number of 50-minute baseline sessions. The purpose of the baseline sessions was to establish the child’s level of social engagement skills prior to the beginning of intervention. The baseline sessions consisted of various activities targeting social engagement skills. Each baseline session was structured to include (a) parent interaction, involving blocks, books, toy farm or play house, etc., (b) familiar adult interaction, involving the graduate clinician that was assigned to the
participant, and included six activities involving a baby doll with food, a baby doll with a blanket, push-car, ball, wind-up toys, and singing two songs, (c) unfamiliar adult interaction, involving the previous six interactive activities with an adult the child had not met, and (d) a triadic interaction. The pre-and post-data pertaining to the familiar adult interaction, unfamiliar adult interaction, and the triadic interaction were each coded and analyzed. For the purposes of the current study, the triadic interaction was the primary focus, which is elaborated upon as follows.

The concluding activity of the baseline session was a triadic interaction between the child, graduate clinician, and assisting graduate clinician. The triadic interaction consisted of 4 interactive activities including a ball, car, music toy, and tambourine. The graduate clinician initiated the interaction by giving the item to the assisting graduate clinician. The assisting graduate clinician would then give the item to the child. The child would then be asked to return the item to the graduate clinician. Upon completion of the assigned number of baseline sessions, the child would then complete 20 sessions of treatment. At the conclusion of the 20 treatment sessions, each child participated in three follow-up sessions. The follow-up sessions were identical in structure and design to the baseline sessions. An outline of the baseline and follow-up measures is included in Appendix A.

**Traditional treatment.** Each child participated in a varying number of traditional 50-minute therapy sessions. As noted above, the number of traditional treatment sessions was dependent on the number of baseline sessions the child participated in. The traditional therapy was patterned after components from the SCERTS model which emphasizes social communication, emotional regulation, and transactional support (Prizant, 2003). The sessions consisted of highly interactive play-based environments. The treatment goals focused on
increasing expressive language, improving plays skills primarily through symbolic play, and improving social interaction skills such as frequency of eye contact, initiating activities, and turn-taking (Acerson, 2011; Hansen, 2011).

**Traditional treatment with the robot.** Upon completion of a set number of traditional treatment sessions, each child began sessions consisting of 40-minutes of traditional therapy and 10-15 minutes of interaction with the robot. The 40-minutes of traditional treatment was similar to the intervention discussed above. The 10-15 minute interaction with the robot was randomly assigned at the beginning, middle, or end of the session. The structure of the robot interaction consisted of a quadratic interaction consisting of the participant, the participant’s mother, the graduate clinician, and Troy. The focus was on increasing joint attention and social engagement skills. During the robot interaction, an additional graduate clinician provided assistance to the child with hand-over-hand support and appropriate modeling. The robot interaction began with an exchange of greetings accompanied by waving. The remainder of the robot interaction focused on group activities targeting an exchange of turns with an object or item (e.g. ball, bubbles, or music toys) or singing with actions. The final activity of the robot interaction consisted of each person saying good-bye to Troy and waving.

All of the above sessions were recorded by two video cameras. The first camera was mounted on the wall and focused on the interaction occurring in the clinic room. The second camera was a handheld camera operated by a student. The handheld camera focused on the child’s face. The recordings from the two cameras were synced together using Final Cut Pro Express™. The use of the two cameras was necessary to code social interactional behaviors of interest.
Data Analysis

The data analysis system used in the current study was adapted in portions from Siebert, Hogan, and Mundy (1982). For the purposes of this study, the triadic interactions that occurred in the pre-and post-intervention sessions were used and compared. Each pre- and post-intervention session was analyzed looking for specific social engagement behaviors that occurred in response to probes presented by the clinicians. As previously mentioned, the triadic interaction was based on four activities. Each activity was presented three times for a total of 12 probes. The social engagement behaviors were calculated based on their occurrence once each probe was presented. The total occurrences of social engagement behaviors in the pre-intervention sessions were compared to the total occurrences calculated from the post-intervention sessions.

The social engagement behaviors that were analyzed were categorized into the following areas: eye contact, reciprocal play, symbolic play, language, and initiating engagement. Eye contact included the occurrence of eye contact between the child and an individual participating in the interaction. Reciprocal play consisted of basic turn-taking routines where the child would return the item appropriately to the correct person. Symbolic play was presented in the form of reciprocal action where the child would be presented with a toy and expected to demonstrate appropriate symbolic play (i.e. feeding the baby). Language consisted of the child making a verbal comment or signing in association with the interaction or activity. Initiating engagement included the child’s verbal request for “more,” the return of the toy following symbolic play, or the return of the item paired with eye contact or language. Appendix B includes the coding manual which was used to analyze the occurrences of social engagement behaviors in the pre- and post-intervention sessions. Detailed guidelines for identifying specific social engagement behaviors, as well as illustrative examples, are presented in the manual.
Coding Reliability

Four graduate clinicians were trained in the analysis system and interjudge reliability was established for each category of behavior. One clinician served as the expert coder and the other coders established reliability with this individual. The percentage of agreement established between the expert and each coder is outlined in Table 2.

Table 2

*Established Reliability between Expert Coder and Individual Coders*

<table>
<thead>
<tr>
<th></th>
<th>Coder 1</th>
<th>Coder 2</th>
<th>Coder 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye Contact</td>
<td>96%</td>
<td>91%</td>
<td>92%</td>
</tr>
<tr>
<td>Reciprocal Action</td>
<td>97%</td>
<td>97%</td>
<td>96%</td>
</tr>
<tr>
<td>Symbolic Play</td>
<td>94%</td>
<td>97%</td>
<td>94%</td>
</tr>
<tr>
<td>Language</td>
<td>99%</td>
<td>97%</td>
<td>100%</td>
</tr>
<tr>
<td>Initiating Request</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Results

The purpose of this study was to identify social engagement behaviors in four children with autism before and after sessions of targeted intervention involving low dose exposure to a robot. Pre- and post-intervention assessments were conducted for each child consisting of four different interaction types (e.g., between child and parent, interaction in a triad, etc.). The current study describes the occurrences of social engagement behaviors during the triadic interaction. Additionally, it should be noted that the variable number of pre-intervention sessions served as the multiple baseline segment of a single subject multiple baseline design. For purposes of this thesis, however, only the pre-and post-sessions are compared. The following is a summary of each child’s performance during pre- and post-intervention assessments in a three-way interaction with two adults. Each child is presented individually.

LR’s Performance

**Baseline and follow-up sessions.** LR participated in six pre-intervention sessions and three post-intervention sessions. Results of LR’s social engagement behaviors in a triadic interaction from pre- and post-intervention sessions are listed by each individual session in Table 3.

LR’s performance for social engagement behaviors showed some improvements but overall his performance was inconsistent. Comparing the pre-and post-intervention sessions, he demonstrated an overall decrease in appropriate eye contact by 12% but an increase in reciprocal action by 11% in a triadic interaction. It was of note that LR’s social engagement behaviors during the post-intervention session number three were significantly lower than his social engagement behaviors in other post-intervention sessions. LR showed a notable decrease for eye
Table 3

LR’s Social Engagement Behaviors in Triadic Interaction

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention Sessions</th>
<th>Post-Intervention Sessions</th>
<th>Diff.</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Eye Contact</td>
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<tr>
<td></td>
<td>58%</td>
<td>75%</td>
<td>92%</td>
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<tr>
<td></td>
<td>(7/12)</td>
<td>(9/12)</td>
<td>(11/12)</td>
</tr>
<tr>
<td>Reciprocal Action</td>
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<tr>
<td></td>
<td>17%</td>
<td>0%</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>(2/12)</td>
<td>(0/12)</td>
<td>(4/12)</td>
</tr>
<tr>
<td>Language</td>
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<td>0%</td>
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<tr>
<td></td>
<td>(0/12)</td>
<td>(0/12)</td>
<td>(0/12)</td>
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<tr>
<td>Initiating Engagement</td>
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<td></td>
<td>(0/12)</td>
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<td>(0/12)</td>
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</tbody>
</table>
contact as well as reciprocal play between the second and third post-intervention sessions. LR showed no change in language or initiating engagement behaviors.

**Clinical observations.** Based on clinical observation in post-intervention sessions, LR demonstrated a consistent increase of successful attempts to pair eye contact with reciprocal action as well as participating in turn-taking routines. LR demonstrated these behaviors during the specified probes which is consistent with the results seen in the first and second post-intervention sessions. LR, also, demonstrated these behaviors during non-specified probe activities. For example, during a post-intervention session, LR demonstrated a lack of participation in a triadic interaction probe. Shortly after the triadic interaction, the clinician introduced a ball to the intervention and LR actively participated with the clinicians by rolling the ball back and forth as well as initiating appropriate eye contact with the clinicians.

**KR’s Performance**

**Baseline and follow-up sessions.** KR participated in five pre-intervention sessions and three post-intervention sessions. KR’s social engagement behaviors in a triadic interaction across each individual session from pre-and post-intervention are presented in Table 4.

KR’s social engagement behaviors were inconsistent across the pre- and post-intervention sessions. KR averaged a decrease of 7% in appropriate eye contact. Although eye contact did decrease, her performance was fairly consistent ranging in between 50% to 83%. KR demonstrated a 17% improvement in reciprocal action with a high in the first post-intervention session of 83%. She showed no changes in language or initiating engagement.

**Clinical observations.** Based on clinical observation comparing pre- and post-intervention sessions, KR demonstrated consistent eye contact throughout the duration of the study with particular increases in post-intervention sessions conducted with a familiar adult.
### KR’s Social Engagement Behaviors in Triadic Interaction

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention Sessions</th>
<th>Post-Intervention Sessions</th>
<th>Post-Total</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Eye Contact</strong></td>
<td>50% (5/10)</td>
<td>58% (7/12)</td>
<td>83% (10/12)</td>
<td>75% (9/12)</td>
</tr>
<tr>
<td><strong>Reciprocal Action</strong></td>
<td>60% (6/10)</td>
<td>42% (5/12)</td>
<td>67% (8/12)</td>
<td>25% (3/12)</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>0% (0/10)</td>
<td>0% (0/12)</td>
<td>0% (0/12)</td>
<td>0% (0/12)</td>
</tr>
<tr>
<td><strong>Initiating Engagement</strong></td>
<td>0% (0/10)</td>
<td>0% (0/12)</td>
<td>0% (0/12)</td>
<td>0% (0/12)</td>
</tr>
</tbody>
</table>
The observed consistency of KR’s eye contact is supported by results presented in Table 4. Clinical observations, also, noted an increase in appropriate behavior during turn-taking routines. For example, KR would receive a toy from a clinician and then appropriately respond to a request to give the toy to a second clinician. The observed increase in reciprocal action is consistent with the 17% increase shown in the results from the study. She, also, demonstrated an increase in vocalizations and requests for hand-over-hand facilitation in signing basic words. For example, KR would consistently place her hand in a clinician’s to request assistance to sign “yes” or “no” when presented with a yes or no question by a clinician. These observations were not consistent with the results from the study; however, they do indicate KR’s attempts to communicate.

**LS’s Performance**

**Baseline and follow-up sessions.** LS participated in four pre-intervention sessions and three post-intervention sessions. Results of LS’s social engagement behaviors in a triadic interaction from pre-and post-intervention session are presented in Table 5. LS demonstrated improvements in social engagement behaviors. He averaged an increase of 6% in appropriate eye contact. Referring to Table 5, LS’s occurrences of appropriate eye contact were fairly consistent throughout all sessions with only slight variations during pre-intervention sessions two and four. LS also demonstrated a 31% increase in reciprocal action. There was an overall increase in reciprocal action across each session with the exception of pre-intervention session three. Language production was relatively consistent during the pre-and post-intervention sessions. There was no change in initiating engagement.
<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention Sessions</th>
<th></th>
<th>Post-Intervention Sessions</th>
<th></th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>Eye Contact</strong></td>
<td>66%</td>
<td>50%</td>
<td>66%</td>
<td>58%</td>
<td>Pre-Total: 60%</td>
</tr>
<tr>
<td></td>
<td>(8/12)</td>
<td>(6/12)</td>
<td>(8/12)</td>
<td>(7/12)</td>
<td></td>
</tr>
<tr>
<td><strong>Reciprocal Action</strong></td>
<td>33%</td>
<td>50%</td>
<td>17%</td>
<td>33%</td>
<td>Pre-Total: 33%</td>
</tr>
<tr>
<td></td>
<td>(4/12)</td>
<td>(6/12)</td>
<td>(2/12)</td>
<td>(4/12)</td>
<td></td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>8%</td>
<td>8%</td>
<td>0%</td>
<td>8%</td>
<td>Pre-Total: 6%</td>
</tr>
<tr>
<td></td>
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<td>(1/12)</td>
<td>(0/12)</td>
<td>(1/12)</td>
<td></td>
</tr>
<tr>
<td><strong>Initiating Engagement</strong></td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>Pre-Total: 0%</td>
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<td></td>
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</table>
**Clinical observations.** Clinical observation comparing pre- and post-intervention indicated that LS showed notable fixations on objects or toys in the pre-intervention sessions limiting his level of engagement as the probes were presented. In contrast, during the post-intervention session, LS showed limited fixation and demonstrated appropriate eye contact paired with the return of an item in a turn-taking routine. These observations are consistent with the eye contact and reciprocal action results presented in Table 5. During the pre- and post-intervention sessions, LS’s language attempts were consistently echolalic utterances in response to a bid presented by the clinician. Although during one post-intervention session, LS responded to a clinician’s verbal utterance by saying “roll to me.” LS’s language results presented in Table 5 are consistent with the clinician observations made regarding his consistent echolalic utterances during the pre-and post-intervention sessions.

**AH’s Performance**

**Baseline and follow-up sessions.** AH participated in three pre-intervention sessions and three post-intervention sessions. The results of AH’s social engagement behaviors in a triadic interaction across individuals sessions are outlined in Table 6.

AH’s performance was inconsistent throughout the sessions. It is important to note that during the first session of baseline, AH became dis-regulated and upset to the extent that the triadic interaction did not take place. She showed an overall decrease in eye contact as well as in reciprocal action. There was no change in the level of language or initiating engagement.

**Clinical observations.** Clinical observations based on AH’s level of appropriate eye contact and reciprocal action were consistent with the results presented in Table 6. AH made minimally attempts to engage in eye contact and reciprocal play during the pre-and post-intervention sessions. During interventions sessions, AH would engage in eye contact and turn-
Table 6

AH’s Social Engagement Behaviors in Triadic Interaction

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention Sessions</th>
<th>Post-Intervention Sessions</th>
<th>Diff.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Eye Contact</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4/12)</td>
<td>(3/12)</td>
<td></td>
</tr>
<tr>
<td>Reciprocal Action</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3/12)</td>
<td>(1/12)</td>
<td></td>
</tr>
<tr>
<td>Language</td>
<td>-</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(0/12)</td>
<td>(0/12)</td>
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<tr>
<td>Initiating Engagement</td>
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<tr>
<td></td>
<td>0%</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0/12)</td>
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</table>

*AH did not participate in a triadic interaction during the first pre-intervention session. See AH’s performance for further information.
taking routines with moderate to maximal assistance from a clinician. Clinical observation, also, showed that during final intervention sessions as well as during post-intervention sessions, AH appeared to make a consistent increase at vocalizing word approximations and sound play. For example, the clinician reported that AH would attempt to make the beginning sound in the word “juice” as well as her name. These clinical observations are contrary to the language results depicted in Table 6 that show no notable change in her level of language pre-and post-intervention.
Discussion

The current study focused on the effect of intervention incorporating low doses of a humanoid robot on the social engagement behaviors of four children with autism. Each child participated in pre- and post-intervention sessions which were analyzed and coded for social engagement behaviors. It was hypothesized that intervention utilizing a robot would facilitate an increase in these behaviors. For the purposes of this study, eye contact, reciprocal action, language, and initiating engagement were all analyzed in the context of a triadic interaction.

Evaluation of Results

The four children in the study varied in age, but they all demonstrated severe deficits in social engagement. The following discussion focuses on each of the behaviors that were examined, and evaluates the intervention outcome for each child.

Reciprocal action. All the children showed improvements in reciprocal action except for AH. The improvements ranged from 11 to 30% depending on the child. These improvements were encouraging because the play-based intervention that occurred with the robot focused on this type of behavior. The 10-minute interaction with the robot was structured to include activities in which the clinician could model appropriate behavior during a turn-taking sequence. These activities also facilitated turn-taking. As previously mentioned, the robot interaction focused on activities such as rolling a ball, playing a musical instrument, and/or pushing a car. These activities were structured to emphasize a back and forth exchange. Therefore, the increase of reciprocal action could be attributed to the structure of the robot interaction being heavily focused on modeling and facilitating turn-taking routines. Clinical observation, also, demonstrated gains in reciprocal action beyond the presented probes. As mentioned earlier, the children demonstrated turn-taking skills often paired with eye contact. The gains made in
reciprocal action could be attributed to the turn-taking structure of the robot interaction. The children were able to participate in a highly supported turn-taking routine with multiple partners (the child’s mother, graduate clinician, and the robot). Therefore, it is likely that the children were able to generalize those turn-taking skills learned in the intervention and apply them to other interactions occurring outside of the given probes.

In considering what the robot specifically added to the intervention to facilitate reciprocal action, one explanation focuses on the simplicity of the robot. Blomgren and Tenggren (n.d.) explained that robots might facilitate social engagement skills because they “appear less intimidating” as well as they “communicate in a limited number of ways, allowing the child [with autism] to focus on the interaction” (p. 2). The robot utilized in this study was programmed to be a fairly simplistic partner that could push a ball or car as well as respond with basic utterances such as “great job.” The robot, Troy, could have generated an increase in reciprocal action because of his simplistic structure and design, which allowed the child’s attention to focus specifically on the turn-taking interaction.

The increase in reciprocal action demonstrated by the participants could also be attributed to the highly predictable nature of the robot interaction. As previously discussed, the entire 10-minute robot interaction was focused on activities that facilitated turn-taking. Kozima and Nakagawa (2004) discussed the high correlation between the predictable nature of robots and the expansion of playful interactions. Due to the consistent structure of the robot interaction, the children in this study were able to quickly become accustomed to the routine and therefore, focus on expanding their reciprocal play skills.

Another possible explanation for the increase of reciprocal action is that the interaction with the robot was always accompanied with human interaction. As each child learned to take
turns with the robot, they were immediately able to generalize those skills to another context involving their mother and/or their clinician. The structure of the quadratic interaction (child, mother, clinician and robot) allowed multiple opportunities for the child to practice the turn-taking routine during the 10-minute interaction.

**Eye contact.** There was a fair amount of variability in eye contact across the four participants. Three of the children showed a decrease and one child produced an increase in eye contact. It should be noted, however, that the simple facial features of the robot were not designed to be a particularly motivating source of eye contact. Thus, the lack of positive change in most of the participants was not unexpected. It was of interest, however, that the one child who did produce gains in eye contact was able to generalize the skill from the robot interaction to a human interaction. It was undetermined if those skills generalized to individuals outside the clinic. Still, it was notable that the child’s mother reported observing him interacting with peers in a more successful and easier manner using eye contact.

Clinical observations, also, indicated that three of the children made gains in establishing appropriate eye contact. It is undetermined if the gains are related to the robot interaction, although the robot interaction was structured in a way to provide maximal support for the child to engage in eye contact with individuals. Given the variability seen across participants and context, further investigation is needed to determine whether these clinical impressions are indicative of meaningful increases in eye contact.

The observed inconsistency of appropriate eye contact could be attributed to several factors. LR showed notable improvement in appropriate eye contact in post-intervention sessions one and two. During the third post-intervention session, LR was extremely dis-regulated as well as uninterested in the specified probes. LR was also the only child that participated in
nine sessions of pre- and post-assessment. The lengthy baseline and follow-up data collection could have contributed to his lack of interest in the presented materials. Due to LR’s performance in the third post-intervention session, the results pertaining to eye contact may not represent his true level of functioning post-intervention. Considering the first two post intervention sessions, it could be argued that LR did make improvements in eye contact which could be linked to the intervention sessions facilitated by the robot.

The inconsistent levels of eye contact observed in the remaining children, KR and AH, could be attributed to a variety of factors. KR had significant health issues throughout the study. When she was not feeling well, KR would often close her eyes and lay on the bean bags. In contrast, AH often appeared to have difficulty regulating during the pre-and post-intervention sessions resulting in a lack of engagement during the specified probes.

**Language and initiating engagement.** None of children in the study experienced a notable change in language or initiating engagement. This could be attributed to the fact that the interactions that occurred with Troy were focused primarily on modeling and practicing responding to bids of engagement in a turn-taking sequence. During the turn-taking sequences with the robot, intervention focused on appropriate reciprocal action, and to a lesser extent, eye contact. Therefore, it makes sense that reciprocal action was more impacted than the areas of language and initiating engagement. It also could be attributed to the children’s generally low level of functioning, which may have made developments in these behaviors beyond the children’s abilities.

Although the results showed no increase of language or initiating engagement, clinical observation did suggest some minimal improvements in these areas. It is difficult to determine if
these gains could be a result of the interaction with the robot, however. Further study will be needed to determine the exact nature of the intervention of these aspects of behavior.

**Limitations**

In considering limitations, it is important to note that this thesis represents an aspect of a larger project. To some extent, some of the limitations discussed are addressed by the larger study. Still, as currently presented, there are a number of factors that could have impacted the observed outcomes in the pre- and post-intervention sessions. Some of these factors are addressed below.

Perhaps the most limiting factor in terms of making general statements concerning the results of the intervention was the high degree of variability between participants. This variability is reflected in a variety of factors. One that likely influenced the results was the varying levels of regulation experienced by the individual children. For example, LS and KR would become aggressive when dis-regulated whereas AH and LR would tantrum and cry. Differing factors were responsible for dis-regulation in each of the children. Once the child became dis-regulated, additional time and attention were required to assist the child in becoming regulated again. This would distract from the activities being presented in the session.

A number of additional variables likely impacted each child’s performance during individual baseline and follow-up sessions. These included individual health, comfort level, fatigue, prior experiences throughout the day, and interest in a specific intervention activity all had the potential to influence the child’s performance. For example, AH’s sessions needed to be scheduled on days that she had not previously been at school. If AH had been to school earlier that day, her attention and regulation were severely compromised and she was unable to participate in the session.
An additional limitation of this study was the complexity of analyzing the social engagement behaviors in a semi-naturalistic context. These analyses were challenging. The behaviors were often subtle. Additionally, analysis was often complicated by unique behaviors produced by each child. For example, KR would frequently demonstrate excessive laughter and smiling in response to no specific external input. LR demonstrated similar affect but during moments of extreme aggression and dis-regulation. Due to the inconsistencies and limited understanding of their behavior, it was challenging to properly code and analyze the observed behaviors.

To address these difficulties, the coding system consisted of specific rules and definitions of categories of behaviors. The coding was performed in a way that strictly adhered to the protocols established in the data analysis system. This was the only way that was discovered in the analysis to produce a reliable coding system. However, this system also had the potential for loss of information. For example, eye contact was coded between the child and an adult as a means to convey social engagement. If the eye contact that occurred was empty (that is to say it lacked meaning and intent), it was still coded as eye contact because it fulfilled the established definition of eye contact in the data analysis system.

An additional limitation was the fact that the intervention was delivered in a 3 month period to fit within a university semester. It is possible that if the intervention were longer it would have produced more notable gains across the behaviors observed. Indicative of this possibility, Robbins, Dautenthal, Boekhorst and Billard (2005) suggested that it required “six months or more for the first breakthrough in the interaction between the therapist and an autistic child to occur” (p. 6). Although in the current three month long study some improvements were
observed, it would be beneficial to extend the length of the intervention to determine if a longer program would have produced more increases in social engagement behaviors.

The various limitations presented are important to take into consideration when viewing the findings. Factors such as the individual differences between children, the length of the intervention, and the complexity of analyzing the data could have influenced the observed outcomes. In the next section some suggestions to address these issues are presented.

**Recommendations for Future Research**

Future research should expand on the success of using the robot to increase reciprocal action. The current study showed notable gains in facilitating reciprocal action skills with the use of the robot. An influential factor, however, was the individual variability between children. In this regard, it will be important to replicate these results with a larger number of participants. Randomly placing these children into conditions of intervention with and without the robot would provide an important evaluation of the current findings. Larger numbers of children would also address, to some degree, the limitations of individual variability discussed above. It should be remembered, however, that individual variation is a prominent characteristics of this diagnostic category. Even in large randomized controlled trials this variability is likely to play some role and must be considered.

Second, an extension of the duration of the study would be helpful in determining if this approach is appropriate for children with autism. As noted above, it would be beneficial to extend the length of the intervention to determine if a longer program would have produced greater intervention outcomes. A longer program would also make it possible to determine the extent to which a child’s initial adjustment to the clinician and the intervention impacted the outcome.
Finally, the analysis of behavior in semi-structured interactions can be challenging, particularly when children bring a number of unique behaviors to these interactions. To some extent, this complexity is inherent in analyzing human behavior. In the current study, it was necessary to examine specific probes in particular contexts to facilitate data analysis. It would be advantageous in future analyses to focus on broader contexts, highlighting more spontaneously produced behavior. Future work should concentrate on the development of analysis systems that can be reliably used to accomplish this end.

**Conclusion**

The current study focused on the effectiveness of utilizing a humanoid robot to facilitate social engagement behaviors in children with autism. The overall results across the participants were inconsistent but reciprocal action showed notable gains. Additionally, clinical observations suggested that the children benefitted from their exposure to the robot. It is difficult to gauge the effect of the internal and external factors that may have influenced the behaviors of the children during the study, however. Additionally, the analysis of social engagement behaviors in a reliable manner required the establishment of a detailed coding manual. At times, the children demonstrated subtle but relevant changes in social engagement behaviors that were not captured by the analysis system. Despite these limitations, the results of the study suggest potential for generalization of social engagement behaviors from the robot to human interaction. Further research should be conducted to establish more conclusively the validity of using a robot to facilitate social engagement behaviors in children with autism.
References


Robots and Children with Autism


TiLAR Team (2012). Coding manual (Unpublished). Brigham Young University, Provo, Utah


Appendix A

Annotated Bibliography


**Purpose of the study:** The study focused on evaluating the effects of utilizing a robot in intervention with children with autism on social engagement behaviors.

**Method:**
*Participants:* The participants in the study included two children diagnosed with ASD. During the year prior to the study, each participant had been enrolled in speech and language intervention at the Brigham Young University Clinic. Both of the participants showed no notable gains in social engagement behaviors during the year of therapy.

*Procedures:* The study focused on evaluating the pre- and post-sessions after intervention using a robot. The pre- and post-sessions involved the participants interacting in play-based activities with a parent and then a graduate clinician. Each child participated in 16 sessions involving a 10-minute triadic interaction involving the child, parent, and the graduate clinician with the robot as a facilitating therapeutic tool. The pre- and post- intervention sessions were recorded and analyzed for the occurrence of social engagement behaviors.

*Results:* The results of the study indicated that one child demonstrated marked improvements in social engagement behaviors whereas the other child showed a variable increase and decrease in various social engagement behaviors. The study reported that according to clinical observations each child showed an increase in social interaction.

*Conclusions:* Intervention involving a robot in low doses with children with autism showed an increase in attempts to interact with others as well as the occurrence of social engagement behaviors.

*Relevance to the current work:* The results from this study indicated the need for further investigation in robot-based intervention. The current study is an expansion of this study.


**Purpose of the work:** The chapter focuses on summarizing the major diagnostic features of autism as well as other predominant characteristics that are associated with the disorder.

**Summary:** Autism is a pervasive development disorder that is diagnosed on the basis of deficits in “social interaction and communication and a markedly restricted repertoire of activity and interests” (p. 70). Autism is commonly associated with mild to profound abnormalities in the development of cognitive skills. The diagnosis of autism is more common in males than females and ranges from 2 to 20 cases per 10,000 individuals. The chapter also describes additional pervasive developmental
disorders: Rett’s Disorder, Childhood Disintegrative Disorder, Asperger’s Disorder, and Pervasive Developmental Disorder Not Otherwise Specified.

**Conclusion:** Autism is a pervasive development disorder that is characterized by deficits in social interaction and communication skills.

**Relevance to the current work:** The chapter provides the definition and characteristics of autism.


**Purpose of the work:** The article outlines guidelines for screening and diagnosing autism developed by a panel of twenty-members from the American Academy of Neurology (AAN). The guidelines were established to assist healthcare providers in the early identification of children with autism.

**Summary:** The guidelines presented in the article identify “two levels of investigation that are necessary to clinically identify children with autism” (p. 534). The first level is referred as “Routine Developmental Surveillance” (p. 534) and focuses on identifying children that may be at risk for developmental delays by the administration of standardized screening tests. Children who fail a routine developmental screening should be immediately screened specifically for autism. Studies suggest that by 18 months behaviors that are indicative of autism include “problems with eye contact, orientating on one’s name, joint attention (the ability to use eye contact and point for social purpose of sharing experiences with others, pretend play, imitation, nonverbal communication, and language development” (p. 535).

The second level, “Diagnosis and Evaluation of Autism,” (p. 535) focuses primarily on differentiating children with autism from other developmental disorders that were previously identified in level one. It is strongly suggested that experienced clinicians administer a variety of assessment procedures to correctly identify the presence of autism. The panel also established a list of recommendations to consider when completing level two. The recommendations include: (a) allow ample time for parent interviews regarding current concerns, (b) observe social and communicative behaviors, (c) “use recommended diagnostic parental and observation instruments” (p. 535), (d) use a multidisciplinary approach for the evaluation process, (d) reevaluate the child within one year of the diagnosis and provided continued monitoring of behaviors, and (e) assess the family resources.

**Conclusions:** The study provides a brief overview of guidelines for the screening and assessment of children with autism. It is suggested that healthcare providers working with children should increase their awareness and knowledge of autism in order to appropriately identify and provide treatment for children with autism.

**Relevance to the current work:** The article describes characteristics that are early indicators of autism.


**Purpose of the work:** The purpose of the article is to discuss the difficulties and advantages in using a robot as a therapeutic tool for children with autism.
**Summary:** Blomgren and Tenggren (n.d.) list several reasons for utilizing a robot as a therapeutic tool. First, robots “appear less intimidating to a child with autism than an actual human” (p. 2). Next, robots create a consistent and predetermined play routine that allows the child to feel comfortable and confident in the interaction. Finally, robots communicate in a limited number of ways which allows the child to focus on the interaction.

Specific difficulties that need to be considered when utilizing a robot in therapy for children with autism are addressed. The interface of the robot (e.g., if it includes bright colors and lights), could be a possible distraction for children with autism. The robot should also be durable to withstand damages caused by the children during the interactions. The use of the robot is also only intended to be operated in the presence of professionals or supervisors that can adjust the functions of the robot to suit the needs of the child.

**Conclusion:** Robots have shown to facilitate growth of social behaviors in children with autism. Although improvements have been seen, it is important to consider the individual needs of the child during the design and implementation process of the robot.

**Relevance to the current work:** The article outlines the components of utilizing a robot as a therapeutic tool.


**Purpose of the work:** The purpose of the paper is to review the literature regarding initiating joint attention in typically developing children and children with autism.

**Summary:** Joint attention refers to a group of behaviors that focus on “communicating with another person about a third entity in a nonverbal way (p. 169). Joint attention is divided into two types, response to joint attention (RJA) and initiation of joint attention (IJA).

Research concludes that the importance of IJA is based on its relationship to the development of language as well as to the overall development of intentional communication. As the development of joint attention occurs, a typical child’s communication expands from including the communication partner to the object as well. In contrast, children with autism demonstrate significant difficulty in the development of IJA. Due to limited IJA, children with autism demonstrate deficits in communication skills. Children with autism primarily communicate for the purposes of requesting and protesting, not for the purposes of social communication.

**Conclusion:** There is a positive correlation between the development of joint attention behaviors and the development of intentional communication. Research suggests that IJA behaviors may be a prerequisite to the acquisition of intentional communication and functional speech.

**Relevance to the current work:** The article discusses the importance of joint attention in developing social engagement skills.

Purpose of the work: The article investigates the role social interaction plays in the development of social understanding.

Summary: Carpendale and Lewis suggest that the development of social understanding occurs within the context of the child’s social world. The extent and the nature of the child’s social interactions will influence the development of the child’s social understanding. Children’s social interactions typically progress from simple dyadic interactions to complex triadic interactions. The article suggests the importance of triadic interactions in the development of social understanding due to their ability to gradually allow the child to establish “knowledge of the world as well as knowledge of other people” (p. 79).

Conclusion: Carpendale and Lewis conclude that a child does not adopt socially available knowledge, but rather, develops social understanding within social interactions.

Relevance to the current work: The article highlights the importance and benefits of focusing on social interaction primarily the context of triadic interactions to develop social understanding.


Purpose of the study: The paper reviewed the various applications of technology-based interventions for children with autism. There are different types of technology-based interventions: indefinite and temporary. The current study focused on temporary instructional aide devices which are gradually faded out of intervention as the target behavior is mastered.

Summary: The review focuses on five examples of temporary instructional aide devices:

1. Tactile and auditory stimulation can be used to prompt children with autism. The goal of the prompts is to “decrease inappropriate and off-task behavior” (p. 168) as well as to promote the increase of social engagement behaviors.
2. Video technology is a widely accepted therapy tool for autism intervention. It requires “very little instruction” (p. 168) and is readily available for children, parents and clinicians to use. Video technology is commonly used as an engaging medium to teach and model appropriate social behaviors.
3. Computer-based interventions have been used to facilitate progress in areas including: problem solving, vocabulary and spelling, and overall communication skills. Research indicates that computer-based intervention improves the target behavior as well as increasing the child’s overall motivation, attention, and decreasing inappropriate behavior.
4. Virtual reality is an intervention tool that allows opportunities to “experience a three-dimensional, computer-generated world in which people can behave and encounter responses to their behavior” (p. 171). Although the application of virtual reality with
children with autism has been limited, studies have shown improved attention and performance.

5. Robots have shown to be a promising intervention tool for children with autism. Research shows that children can benefit from robots because they create a simplified social environment and predictable interactions. Robots can be used to facilitate social interaction skills by engaging children in basic imitation and turn-taking activities as well as acting as an object of shared attention to encourage interaction with others. The Aurora Project, led by Kerstin Dautenhahn, suggests that “(a) robots are safe interaction partners for children, (b) children are not afraid of the robot, (c) children are sufficiently motivated to interact with the robot over a period of 10 min or longer, (d) children are more interested in the robot in ‘reactive’ mode as compared to the robot showing rigid, repetitive, non-interactive behavior, and (e) children show no distress or behavior problems when the robot behaves reactively but not completely predictably” (p. 172). Although research indicates that robots may be an effective tool for children with autism, a considerable amount of additional research needs to be completed in this area.

**Conclusion:** Technology-based intervention with children with autism includes the use of (a) tactile and auditory prompting devices, (b) video-based instruction, (c) computers, (d) virtual reality, and (e) robots. Each area shows potential but further research needs to be completed to determine if these technology-based interventions are cost-effective and if they are more effective than traditional therapy.

**Relevance to the current work:** The article discusses the use of robotics to facilitate social interaction in intervention with children with autism.


**Purpose of the study:** The paper describes the integration of robots into traditional therapy to promote child-human interaction.

**Method:**

*Participants:* Two children diagnosed with ASD participated in 16-session of 50-minute traditional therapy with 10-15 minutes dedicated to robot-based interactions.

*Procedures:* Coding analyzed the social engagement behaviors that occurred during a pre- and post-trial evaluation. Each child interacted with an unfamiliar adult focused on engaging the child in social interaction. Coding focused on separating engagement from non-engagement behaviors. Engagement behaviors were then divided into initiating and responding with social cues such as eye contact and language marked for coding.

**Results:** Both children showed significant increases in pro-social interactions in the post-trial evaluation compared to the pre-trial evaluation.
**Conclusion:** The preliminary evidence indicates that robot-based interaction can promote positive child-human interaction. In January 2011, a 14-week staggered start approach will begin involving four children with ASD. The incorporation of the staggered start will better provide a way to measure changes from traditional therapy to robotic therapy.

**Relevance to the current work:** The results indicated potential in using robots to facilitate social interaction.


**Purpose of the study:** The study focused on analyzing pre- and post- assessments after intervention utilizing a humanoid robot.

**Method:**
*Participants:* The participants in the study included two children diagnosed with ASD. Prior to the initiation of the study, both of the children were enrolled in the Brigham Young University Clinic for traditional speech and language therapy. During that year, neither of the children had made significant progress in social engagement behaviors.

*Procedures:* The study evaluated two interaction types: interaction with two adults and an interaction with an unfamiliar adult. The pre- and post- intervention assessments were analyzed and coded for social engagement behaviors demonstrated by the children.

*Results:* The children demonstrated an increase in social engagement behaviors during post-intervention sessions.

*Conclusions:* The study concluded that low-dose, play-based intervention utilizing a robot increases and generalizes social engagement behaviors to human interactional partners.

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


**Purpose of the work:** Children with autism typically display deficits in joint attention and symbolic play. These two areas have been studied but rarely targeted in intervention. The current study examines the efficacy of targeting joint attention and symbolic play in intervention.

**Method:**
*Participants:* The participants in the study were 58 children with autism between the ages of 3-4 years.
Procedures: The children were randomized into three different groups: joint attention intervention, symbolic play intervention, and a control group. The intervention was conducted daily in 30-minute sessions for 5-6 weeks. Structured pre-and post-assessments of joint attention, symbolic play, and mother-child interactions were collected by independent assessors.

Results: The results indicated that both intervention groups improved significantly compared to the control group. The children in the joint attention intervention group initiated significantly more attempts at showing and responsiveness to joint attention during the structure joint attention assessment. The children also showed more child-initiated joint attention during the mother-child interaction.

The children in the symbolic play intervention group showed diverse types of symbolic play in the interactions with their mothers. They also showed higher play levels on the structured symbolic play assessments.

Conclusion: This randomized controlled study provides promising results for targeting joint attention and symbolic play in intervention for children with autism.

Relevance to the current work: The study provides evidence indicating that joint attention and symbolic play skills can be facilitated through intervention.


Purpose of the study: A case study investigating the effectiveness of using a humanoid robot to facilitate communication in typical and handicapped children.

Method:
Participants: The participants in the study were 14 typical children (from 4 months to 9 years of age) and a 6-year-old boy with high-functioning autism.

Procedures: Each of the children participated in an interaction with the robot. First, the children were seated alone in front of the robot. Then the child’s mother would come in and sit next to the child. The interaction would continue until the child no longer showed interested in the robot.

Results: The results indicated that the typical children progressed through phases of interaction with the robot. First they recognized the robot as a moving object then they recognized that the robot as “an autonomous, subjective system that possesses attention and emotion as a source of the physical movement” (p. 476). Next, they realized that the robot’s response had a temporal relation with what they had done to the robot and then they finally recognized the robot as a social communicative partner. The average interaction time was about 30 minutes.
The child with autism naturally “got into a social loop” with the robot. The child with autism was able to engage into playful interactions with the robot ranging from everyday social interactions such as giving and showing an object to “ad lib games and hide-and–seek” (p. 476).

**Conclusion:** The authors conclude that the use of a humanoid robot can facilitate emergence of social interaction skills.

**Relevance to the current work:** The article discusses an interaction between a child with autism and humanoid robot.


**Purpose of the study:** The study investigated how robots facilitate and develop social interactions with children with autism longitudinally.

**Methods:**

*Participants:* The participants in the study were two male and three female children diagnosed with autism.

*Procedures:* Each of the children participated in five sessions of 5-10 minutes each month for four months. The sessions were structured with two experimental environments with a robot and some blocks on the table. In the first experimental environment, the robot responded with simple phrases. Then in later sessions, the robot would intentionally push or drop objects off the table without speaking to the child.

**Results:** Three out of the five children made attempts to interact with the robot. Two of three children, who interacted with the robot, showed developmental changes and showed an increase in varied interactions with the robot.

**Conclusion:** Based on the results from the study, the authors suggest that robot have potential to socially interact with children with autism.

Purpose of the work: Mundy and Sigman (2006) discuss the development of joint attention and social competence. They identify various models to explain the relationship between joint attention and social competence.

Summary: The development of social competence is dependent on the development of joint attention. Joint attention can be divided into three categories: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). Typical children develop the different forms of joint attention between 3 and 18 months of age. However, children with autism usually demonstrate marked deficits in the forms of joint attention, specifically IJA and RJA.

Based on previous research, four models have been developed to demonstrate the link between joint attention and social competence. The four models are: the caregiver/scaffolding model, the social-cognitive model, the social motivation model, and the neurodevelopmental executive function model.

Conclusion: Current research is beginning to determine the nature of the connection between joint attention skills and the development of social competence.

Relevance to the current work: The article discusses joint attention and it’s relation to social competence.


Purpose of the work: The chapter discusses the social-emotional development of children with autism. The chapter also highlights the differences of social-emotional development of children with autism compared to children with other disabilities or without disabilities.

Summary: Social-emotional development is referred as the “child’s capacity to experience and express a variety of emotional states, to regulate emotional arousal, to establish secure and positive relationship, and to develop a sense of self as distinct from others” (p. 253). In children with autism, early features that characterize social-emotional development are a lack of reciprocal eye contact, infrequent or absence social smile, and less interest in the human face. These features typically distinguish children with autism from children with other developmental disabilities as well as typically developing children.

Research has identified several components of social-emotional development that are challenging for children with autism. The following areas are: joint attention, face perception, emotion recognition, gesture and imitation, theory of mind, executive function. The chapter discusses how each of these areas might help explain the overall social functioning demonstrated by children with autism.
Conclusion: Differences in social-emotional development, particularly social interaction, are frequently highlighted as the most salient feature of children with autism.

Relevance to the current work: The chapter discusses the components of social-emotional development apparent in children with autism.


Purpose of the work: Prizant et al. (2003) present an overview of the SCERTS model, “a comprehensive, multidisciplinary approach to enhancing communication and socioemotional abilities” (p. 298) of children with autism.

Summary: Recently a comprehensive review by an expert panel on ASD concluded that various intervention approaches have demonstrated positive outcomes, but not all children benefit equally from one approach. Prizant et al. (2003) developed a model to address the limitations presented in other intervention approaches. The SCERTS model was derived from two decades of empirical and clinical research and was established to address the core deficits of ASD. The core dimensions of the SCERTS model are Social Communication, Emotional Regulation, and Transactional Support. The SCERTS model consists of a comprehensive program focused on the primary developmental dimensions (social communication, emotional regulation, and transactional support) to support children with ASD and their families.

Conclusion: The SCERTS model is a comprehensive intervention program for children with ASD and their families. It addresses the core deficits of ASD by focusing on social communication, emotional regulation, and transactional support.

Relevance to the current work: The article presents an intervention model for children with autism that focuses on communication and socioemotional abilities.


Purpose of the study: The study investigated the social engagement behaviors of two children with ASD during low-dose, highly interactive intervention sessions utilizing a robot. The study focused on analyzing the initiation of social engagement behaviors demonstrated by each child.

Method:

Participants: The participants in the study included two children diagnosed with ASD. Prior to the initiation of the study, both of the children were enrolled in the Brigham Young University
Clinic for traditional speech and language therapy. During that year, neither of the children had made significant progress in social engagement behaviors.

Procedures: The children participated in 16 intervention sessions lasting 50 minutes. During each of the 50 minute sessions, 10-15 minutes were devoted to a triadic interaction utilizing a humanoid robot. Each triadic interaction was analyzed and coded for social engagement behaviors. The current study analyzed the following initiating social engagement behaviors: language, affect, imitation, and eye contact.

Results: Each participant demonstrated growth in initiating social engagement behaviors in the presence of the robot as well as with adults.

Conclusions: The study concluded that intervention utilizing a robot produces an increase in social engagement behaviors, particularly eye contact. The study suggests the need for further research to investigate the potential use of a robot to facilitate 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: Ricks discusses the development of a humanoid robot as a therapeutic tool to be used in intervention for children with autism.

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

Procedures: Each child participated in a triadic interaction that included a graduate clinician, an assisting graduate clinician, and the robot. The robot was programmed with basic facial expressions and actions (pushing a ball). The goal of the triadic interaction was to establish engagement between the child and the robot.

Results: The two typical participants interacted with the clinicians and robot during the triadic interaction. The child with developmental and behavioral handicaps demonstrated positive affect while engaging with the robot and the clinicians. The child with autism initially showed mild interest in the robot. However during later sessions, the child with autism showed positive affect and was highly motivated to engage in the triadic interaction.
Conclusions: The results from the study show that the robot has potential to facilitate social engagement in therapy for children. Further research should be conducted to determine the long-term benefits of utilizing a robot in therapy for children with autism.

Relevance to the current work: This article described the design and characteristics of the robot used in the current study.


Purpose of the work: The work presented in the article is part of the Aurora project, which investigates the use of robots as therapeutic or educational tools specifically for use with children with autism. This study specifically describes a longitudinal study conducted with children with autism that were exposed to a humanoid robot over a period of several months.

Methods:
Participants: The participants in the study were four children between the ages of 5-10 years old that had previously been diagnosed with Autism.

Procedures: The sessions with the robot were designed to progressively “move from very simple exposure to the robot to more complex opportunities for interaction” (p. 9). Each interaction lasted as long as the child was comfortable participating in the interaction. The average duration of the interactions lasted approximately three minutes. Each session was video recorded and coded for social behaviors.

Results: The results indicated that the children’s activities in their interactional context showed gains in social interaction skills (imitation, role-switching and turn-taking) as well as communicative competence.

Conclusion: The study demonstrated the need and benefit of long-term studies to show the full potential of using a robot as a therapy tool for children with autism.

Relevance to the work: The study used a humanoid robot to facilitate social interaction skills.


Purpose of the work: The articles reviews research conducted in the past 15 years on social skills intervention for children with autism.

Summary: Due to the increasing number of children being diagnosed with autism, the need for effective intervention is necessary. Early intervention programs focused on preparing and teaching children with autism to be academically mainstreamed into regular education.
classrooms. Scattone (2007) states the importance of intervention programs including social skills goals because it is as important as teaching academic skills for this population of children. Children with autism have a profound deficit in social skills; therefore intervention should target the development and growth of social skills.

Early social skills intervention targeted simple behaviors such as orientating toward another person and eye contact. Over the years, social skills intervention has progressed to include goals addressing “play, perspective taking, and conversation skills” (p. 717). Intervention can target social goals through various means. The article addresses the application of the following techniques to target social skills goals: video modeling, self-management, priming, written scripts, social stories, and natural settings.

**Conclusion:** Intervention for children with autism has become more sophisticated over the past 15 years. Intervention has progressed from focusing on academic skills to social skill remediation which has been shown to produce more favorable outcomes. Targeting social skills through various intervention techniques (video modeling, self-management, priming, written scripts, social stories, and natural settings) has shown to generalize across settings as well as increase independence and self-reliance for children with autism.

**Relevance to the current work:** The article discusses the importance of social skills intervention for improving behaviors in children with autism.


**Purpose of the study:** The purpose of the article is to discuss how robots will make an impact on our clinical understanding, diagnosis, and treatment of autism.

**Method:**

**Procedures:** Scassellati and a research team created a robot named ESRA. ESRA was programmed to demonstrate various facial expressions in order to determine the child’s level of attention and elicit particular social skills and behaviors from the child.

The study utilized two different methods for obtaining data for diagnosis. The first method was through passive sensing. Passive sensing involves motion sensors to detect eye gaze, position (e.g., an individual’s position as they move in a room), and vocal prosody. The second method was an interactive social cue measurement. This type of method utilized an interactive robot to gather data specifically in the contexts of a social interaction.

**Results:** The results indicated that the typical children initially showed the most interest in the robot. They would often make more attempts to engage with the robot but they would gradually
Robots and Children with Autism

lose interest as time passed. The children with autism would attend and make attempts to engage in interaction with the robot, regardless of the actions of the robot.

**Conclusions:** The use of an interactive robot assisted in the collection of objective and quantitative data during social interactions. Further research needs to be conducted to develop a more interactive robot that would be effective in intervention sessions for children with autism.

**Relevance to current work:** The article discussed ways to collect data from social interactions conducted between children with autism and an interactive robot.


**Purpose of the work:** Seibert, Hogan, and Mundy described how interactional competencies which develop in the first few years of life form the foundation for all further social and communicative developments. If delays in social and communicative developments can be identified early then changes can be made to effectively facilitate social development. The Early Social-Communication Scales (ESCS) provides a model and an instrument to assess interactional competencies.

**Summary:** The ESCS is based on five organizational levels and can be administered as a caregiver questionnaire or a formal assessment. *Level 0: Reflexive or Responsive* occurs in the first two months of a child’s life. The level is characterized by reflexive or responsive behaviors because the child has not acquired more advanced levels of interactive skills. *Level 1: Simple, Voluntary Interactions* occurs between 2 to 7 months. The infant begins to demonstrate voluntary control over behavior patterns. The child initiates interaction through gestures and eye gaze. *Level 2: Complex, Differentiated Interactions* occurs between 5 to 12 months of age. The child's level of interaction increases in complexity, where the child alternates gaze between their communicative partner and an object of interest, and can establish sustained joint attention. *Level 3: Immediate Modification of Interactions to Feedback* occurs between 13 to 21 months. During this level, the child can deliberately modify his or her actions to the current situation and communicative partner. *Level 4: Anticipatory Regulation of Interactions* occurs between 18 and 22 months. The level is characterized by symbolic or representational thought where the child can anticipate the consequences of their own actions. During this level, language abilities also begin to progress from conventional signal level to a symbolic level.

**Conclusions:** The ESCS provides a method to determine the interactional competencies that form the foundation of social and communicative developments.

**Relevance to the current work:** The article discusses the emergence of social skills.
Robots and Children with Autism


**Purpose of the work:** The chapter discusses the spectrum of pervasive developmental disorders which includes Autistic Disorder, Rett’s Disorder, Asperger’s Disorder, Childhood Disintegrative Disorder and Pervasive Developmental Disorder Not Otherwise Specified.

**Summary:** Autistic Disorder or autism is a pervasive developmental disorder. Deficits in the areas of social development and communication form the core of autism. The diagnostic criteria for autism include impairments in social interaction, social communication and play, and restricted patterns of interest. The onset of autism typically occurs around the age of 3.

**Conclusion:** Autism is a developmental disorder that consists of deficits in social functioning and communication.

**Relevance to the current work:** The chapter provides a definition and describes the characteristics of autism.


**Purpose of the work:** Westby presented the social and cognitive underpinnings of language and communicative competence as well as the various factors that can influence the development of social and communicative competence.

**Summary:** Theory of mind (ToM) is an essential concept for social interacting that develops in children early in life. ToM refers to the child’s ability to recognize that others have emotions and experiences that may be different from their own. The concept of ToM is related to the idea of intersubjectivity. Intersubjectivity refers to the “interfacing of mind with other persons” (p. 136). The development of intersubjectivity is dependent on joint attention skills. Westby defines joint attention as “the integration of information about self-experience of an object or event with information about how others experience the same object or event” (p. 137). Joint attention can be divided into three different types: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). RJA occurs when the child follows the direction of eye gaze, gesture, or head turns of another person whereas IJA involves the child using eye contact or gestures to spontaneously initiate interaction with a communicative partner. IBR occurs when the child uses eye contact and gestures to initiate interaction with another person in an attempt to request aid in obtaining an object or event. According to research, a majority of children with autism develop RJA and IBR, but continue to show impairments in IJA.
Westby states that social competence is reflected in RJA and IJA. These types of joint attention cannot be trained outside of meaningful contexts therefore the child must be motivated to engage with others that will facilitate RJA and IJA.

**Conclusions:** The development of joint attention behaviors is essential for social communication. Children with autism typically exhibit impairments in IJA behaviors. Deficits in these areas greatly impact the social development as well as other aspects of the child’s life. The chapter concludes with emphasizing the importance of targeting these emerging social behaviors in intervention for children with ASD.

**Relevance to the current work:** This chapter described the development of social and communicative competence. It also provided definitions of the three types of joint attention.
Appendix B

Outline of Baseline and Follow-Up Measures

**BASELINE/FOLLOW-UP**

**DATE_________________**

**Parent**

5-7 minutes; book, farm, stuffed animals, pizza, blocks

**Familiar Adult**

**Baby**

Present baby with blanket □ □ □

Present baby with food □ □ □

**Push car**

Present the car; Push the car to the child □ □ □

Say “PUSH IT TO ME”

**Two Songs**

Itsy Bitsy Spider □

Popcorn Popping □

**Windup Toys**

Present 3 wind-up toys individually; initiate toy 3x

#1 Wind-up toy □ □ □

#2 Wind-up toy □ □ □

#3 Wind-up toy □ □ □

Say “WATCH THIS”

**Less Familiar Adult**

**Baby**

Present baby with blanket □ □ □

Present baby with food □ □ □

**Push car**

Present the car; Push the car to the child □ □ □

Say “PUSH IT TO ME”

**Two Songs**

Itsy Bitsy Spider □

Popcorn Popping □

**Windup Toys**

Present 3 wind-up toys individually; initiate toy 3x

#1 Wind-up toy □ □ □

#2 Wind-up toy □ □ □

#3 Wind-up toy □ □ □

Say “WATCH THIS”

**Noisy Ball**

Roll the ball to client □ □ □

Say “ROLL IT TO ME” or “MY TURN”

**Triadic Interaction**

Present car, tambourine, music toy, and ball

Push to clinician then to child □ □ □

Give to clinician then to child □ □ □

Push to clinician then to child □ □ □

Give to clinician then to child □ □ □
Appendix C

Coding Manual

Definitions

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

2. Invalid Probe: probe is invalid if the clinician does not verbally say the proper phrases associated with the interaction. Take the 1st 3 valid probes.

3. 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.
3. Don’t code your own client.
Robots and Children with Autism

Familiar Adult

Baby with blanket
Probe begins: when the materials leave the clinician’s hands
Probe ends: 20 seconds after the probe began

Eye Contact: ___ ___ ___ ___

Symbolic play:
Child cuddles, hugs, kisses, or rocks baby with or without blanket,
Puts on blanket/wraps up baby,
Covers self or clinician

Self ___ ___ ___ ___

Toy ___ ___ ___ ___

Clinician ___ ___ ___ ___

Initiating: Following symbolic play, hands item back to clinician ___ ___ ___ ___

Language: Signs or speaks about baby or blanket topic ___ ___ ___ ___

Baby with food
Probe begins: when the materials leave the clinician’s hands
Probe ends: 20 seconds after the probe began

Eye Contact: ___ ___ ___ ___

Symbolic play:
Code Feed baby with bottle or spoon

Code Feeds self or clinician with bottle or spoon

Self ___ ___ ___ ___

Toy ___ ___ ___ ___

Clinician ___ ___ ___ ___

Initiating: Following symbolic play, hands item back to clinician ___ ___ ___ ___

Code if feeds self or baby and then feeds clinician

Don’t code if child feeds clinician and then self or baby

Language: Signs or speaks about baby or food topic ___ ___ ___ ___

Singing

Note: Coding begins at beginning of song and proceeds until 5 seconds post completion of the song

Eye Contact: ___ ___ ___ ___

Reciprocal Action: Participates with correct actions of song ___ ___ ___ ___

Reciprocal Action: Singing along with clinician ___ ___ ___ ___

Initiating: Request repeat of song or begins to sing song again within 5 seconds ___ ___ ___ ___
Robots and Children with Autism

Ball
**Probe begins:** when clinician finishes saying: Push to me
**Probe ends:** Either 20 seconds after the probe or when a verbal bid is made to change the interaction.
**Code:** if the ball makes it back in ANY WAY to the clinician
**Don’t Code:** 1. If the clinician physically takes item away
2. If the clinician moves significantly to receive the item

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<tr>
<th>Eye Contact:</th>
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<tr>
<td>Reciprocal Action: Returning ball to clinician</td>
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<tr>
<td>Language: Signs or speaks about ball or about activity topic</td>
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<tr>
<td>Initiating: At conclusion of probe, child says or signs “again” or “more”</td>
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Push car
**Probe begins:** when clinician finishes saying: Push to me
**Probe ends:** Either 20 seconds after the probe or when a verbal bid is made to change the interaction.
**Code:** if the car makes it back in ANY WAY to the clinician
**Don’t Code:** 1. If the clinician physically takes item away
2. If the clinician moves significantly to receive the item

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<th>Eye Contact:</th>
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<tbody>
<tr>
<td>Reciprocal Action: Returning car to clinician</td>
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<tr>
<td>Language: Signs or speaks about car or about activity topic</td>
<td>□□□□□</td>
</tr>
<tr>
<td>Initiating: At conclusion of probe, child says or signs “again” or “more”</td>
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Wind-up Toys
**Probe begins:** when clinician finishes saying: Watch this
**Probe ends:** Either 20 seconds after the probe or when a verbal bid is made to change the interaction.
**Code:** If child gives toy back to clinician independently
**Don’t Code:** 1. If child gives toy back to clinician with a verbal prompt or a tactile prompt
2. If child doesn’t give toy to clinician

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<th>Initiating prototypes:</th>
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<tr>
<td>Eye Contact:</td>
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<tr>
<td>Initiating: Give to clinician independently</td>
<td>□□□□□</td>
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<tr>
<td>Language: signs or speaks about wind-up toys or activity topic</td>
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Initiating request: Handing or making available to clinician *paired with eye contact* OR
Handing or making available to clinician *paired with language* (signs or words)

□□□□□□□□□
### Unfamiliar Adult

**Baby with blanket**
- **Probe begins:** when the materials leave the clinician’s hands
- **Probe ends:** 20 seconds after the probe

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<th><strong>Eye Contact:</strong></th>
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<tbody>
<tr>
<td><strong>Symbolic play:</strong></td>
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</tr>
<tr>
<td>Cuddle, hug, kiss, or rock baby with or without blanket</td>
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<tr>
<td>Put on blanket/wrap up baby</td>
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<tr>
<td>Cover self or clinician</td>
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| **Self** |   |   |   |
| **Toy**  |   |   |   |
| **Clinician** |   |   |   |

**Initiating:** Following symbolic play, hands item back to clinician |   |   |   |
**Language:** Signs or speaks about baby or blanket topic |   |   |   |

---

**Baby with food**
- **Probe begins:** when the materials leave the clinician’s hands
- **Probe ends:** 20 seconds after the probe

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<th><strong>Eye Contact:</strong></th>
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<tbody>
<tr>
<td><strong>Symbolic play:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Code</strong> Feed baby with bottle or spoon</td>
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<tr>
<td><strong>Code</strong> Feeds self or clinician with bottle or spoon</td>
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| **Self** |   |   |   |
| **Toy**  |   |   |   |
| **Clinician** |   |   |   |

**Initiating:** Following symbolic play, hands item back to clinician |   |   |   |

**Code** if feeds self or baby **and then** feeds clinician
**Don't code** if child feeds clinician and then self or baby

**Language:** Signs or speaks about baby or food topic |   |   |   |

---

**Singing**

**Note:** Coding begins at beginning of song and proceeds until 5 seconds post completion of the song

<table>
<thead>
<tr>
<th><strong>Eye Contact:</strong></th>
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<tbody>
<tr>
<td><strong>Reciprocal Action:</strong> Participates with correct actions of song</td>
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</tr>
<tr>
<td><strong>Reciprocal Action:</strong> Singing along with clinician</td>
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</tbody>
</table>

**Initiating:** Request repeat of song or begins to sing song again within 5 seconds |   |   |   |
Robots and Children with Autism

<table>
<thead>
<tr>
<th>Ball</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probe begins:</strong> when clinician finishes saying: Push to me</td>
</tr>
<tr>
<td><strong>Probe ends:</strong> Either 20 seconds after the probe or when a verbal bid is made to change the interaction.</td>
</tr>
<tr>
<td><strong>Code:</strong> if the ball makes it back in ANY WAY to the clinician</td>
</tr>
<tr>
<td><strong>Don't Code:</strong> 1. If the clinician physically takes item away</td>
</tr>
<tr>
<td>2. If the clinician moves significantly to receive the item</td>
</tr>
<tr>
<td><strong>Eye Contact:</strong></td>
</tr>
<tr>
<td><strong>Reciprocal Action:</strong> Returning ball to clinician</td>
</tr>
<tr>
<td><strong>Language:</strong> Signs or speaks about ball or about activity topic</td>
</tr>
<tr>
<td><strong>Initiating:</strong> At conclusion of probe, child says or signs “again” or “more”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Push car</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probe begins:</strong> when clinician finishes saying: Push to me</td>
</tr>
<tr>
<td><strong>Probe ends:</strong> Either 20 seconds after the probe or when a verbal bid is made to change the interaction.</td>
</tr>
<tr>
<td><strong>Code:</strong> if the car makes it back in ANY WAY to the clinician</td>
</tr>
<tr>
<td><strong>Don't Code:</strong> 1. If the clinician physically takes item away</td>
</tr>
<tr>
<td>2. If the clinician moves significantly to receive the item</td>
</tr>
<tr>
<td><strong>Eye Contact:</strong></td>
</tr>
<tr>
<td><strong>Reciprocal Action:</strong> Returning car to clinician</td>
</tr>
<tr>
<td><strong>Language:</strong> Signs or speaks about car or about activity topic</td>
</tr>
<tr>
<td><strong>Initiating:</strong> At conclusion of probe, child says or signs “again” or “more”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind-up Toys</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probe begins:</strong> when clinician finishes saying: Watch this</td>
</tr>
<tr>
<td><strong>Probe ends:</strong> Either 20 seconds after the probe or when a verbal bid is made to change the interaction.</td>
</tr>
<tr>
<td><strong>Code:</strong> If child gives toy to clinician independently</td>
</tr>
<tr>
<td><strong>Don't Code:</strong> 1. If child gives toy back to clinician with a verbal prompt or a tactile prompt</td>
</tr>
<tr>
<td>2. If child doesn’t give toy to clinician</td>
</tr>
<tr>
<td><strong>Initiating prototypes:</strong></td>
</tr>
<tr>
<td><strong>Eye Contact:</strong></td>
</tr>
<tr>
<td><strong>Initiating:</strong> Give to clinician independently</td>
</tr>
<tr>
<td><strong>Language:</strong> signs or speaks about wind-up toys or activity topic</td>
</tr>
<tr>
<td><strong>Initiating request:</strong> Handing or making available to clinician paired with eye contact OR</td>
</tr>
<tr>
<td>Handing or making available to clinician paired with language (signs or words)</td>
</tr>
</tbody>
</table>
**Triadic Interaction**

**Probe begins:** with first hand-off (First clinician passing toy paired with saying “Give to ____”)

**Probe ends:** 1. With ANY clinician taking the toy away from child (for the probe to end the clinician MUST have the toy in hand)
2. A clinician making a bid to end the interaction (a bid consists of a change of phrasing “Can I have the toy?” etc. aka clinician trying to retrieve the item with some sort of verbal request)

**Code:** the item INDEPENDENTLY makes it back to the correct clinician

- **Eye Contact:**

- **Reciprocal Action:** Returning item to clinician independently

- **Language:** Signs or speaks about ball or about activity topic

- **Initiating:** At a conclusion of a full probe, child says or signs “again” or “more”