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The Effect of Utilizing a Humanoid Robot on Social Engagement Behaviors in Children with Autism during Interaction with a Familiar Adult

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A thesis submitted to the faculty of
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ABSTRACT

The Effect of Utilizing a Humanoid Robot on Social Engagement Behaviors in Children with Autism During Interaction with a Familiar Adult

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This study focused on intervention using a humanoid robot to facilitate social engagement and joint attention in four children with autism. Intervention was conducted over a three month period, with each child receiving pre-testing, intervention, and post-testing. Intervention was based on the SCERTS model (Prizant, Wetherby, Rubin, & Laurent, 2003). Pre- and post-testing involved interactions with a parent, a familiar adult interaction, a less-familiar adult interaction, and a triadic interaction. This study focuses on the baseline and follow-up testing from the interaction with the familiar adult. Following a period of traditional intervention, sessions involving a humanoid robot (named Troy) were conducted. The robot was integrated into the therapy in a low dose model, meaning that during a 50-minute therapy session, approximately 10 minutes were designated to interactions using the robot to facilitate the interaction. Pre- and post-intervention assessments were recorded, analyzed, and coded for social engagement behaviors. Results comparing baseline to follow-up assessments of the interactions with the familiar adult indicated that the most notable changes were observed in reciprocal action and eye contact. Little change was noted in initiation of social engagement, symbolic play, and language. The implications of these results are discussed and recommendations for future research are provided.

Keywords: autism, robot, joint attention, social engagement

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Description of Structure and Content

The current thesis is presented in a hybrid format in which the current journal publication format is blended with the traditional thesis requirements. This thesis report reflects the current length and style standards for articles published in peer reviewed journals in the field of communication disorders. Appendix A includes table results for each participant. Appendix B consists of an annotated bibliography. Appendix C provides an outline of baseline and follow-up measures. Appendix D includes the coding manual used for data analysis.

Introduction

Autism is a prevalent behavioral syndrome which is primarily defined by delays in social communication abilities, primarily social engagement and joint attention. Treatment approaches for autism have focused on addressing these social communication deficits. A relatively new intervention approach which is under investigation involves the use of robots as a therapy tool to facilitate social engagement behaviors.

Nature of Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) represents a spectrum of disabilities in the areas of communication, behavior, and social interaction. Several disorders fall within the autism spectrum, including: autism, Asperger Syndrome, Pervasive Development Disorder Not Otherwise Specified, Rett's Disorder, and Childhood Disintegrative Disorder (American Psychiatric Association, 2000). Of these disorders, autism is the most prevalent, being the third most common developmental disability, and affects more than 1 in 500 children within the United States (Blackwell, 2001). *Autism* is "a behavioral syndrome, present from early life and defined by deficient social interaction, language and communication, and play" (Rapin, 1991, p. 751). According to the Diagnostic and Statistical Manual of Mental Disorder, Fourth Edition, Text Revision (DSM-IV-TR), in order for an individual to be diagnosed with autism, the person must have shown symptoms since infancy or childhood and exhibit delays or abnormal functioning within three categories of behaviors: social interaction, communication, and symbolic or imaginative play (American Psychiatric Association, 2000). Individuals with autism typically exhibit a lack of social engagement due to limited development of joint attention (JA) (Westby, 2010).

Social Engagement and Joint Attention

Impairment in social engagement is one of the defining characteristics of autism. For the purposes of this study, *social engagement* has been defined as “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 exhibit limited social engagement due to a lack of development of JA, a term which refers to 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. 169).

The primary goal of JA is to establish each communicative partner’s focus on a common object or event (Seibert, Hogan, & Mundy, 1982). Westby (2010) described three categories of JA which include: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). RJA involves the ability of a child to follow another person’s direction of gaze, head turn, or gestures towards a specific event or object. IJA entails a child’s use of eye contact or gestures to independently and spontaneously initiate joint attention with a communicative partner. In IBR, the child uses eye contact and gestures to gain the attention of a communicative partner, in order to obtain assistance obtaining a desired object or event (Westby, 2010). JA or the “integration of information about self-experience of an object or event with information about how others experience the same object or event” (Westby, 2010, p. 137) is essential in order for children to experience social engagement with their communicative partners.

Children with autism typically exhibit “diminished frequency and referential use of eye contact and other joint attention behaviors such as giving, showing, pointing at objects, [and] following points” (Bruinsma et al., 2004, p. 171). JA contributes to social interaction and social engagement, as well as overall language development throughout an individual's lifetime (Mundy & Sigman, 2006). Therefore, targeting social engagement through JA has been incorporated into treatment for autism (Kasari, Freeman, & Paparella, 2006; Mundy & Crowson, 1997). For example, in an investigation employing a randomized controlled design, Kasari et al. (2006) targeted social engagement through JA. One of the groups received a short sequence of discrete trial instruction followed by prelinguistic mileu therapy. This child-centered approach allowed for increased opportunities for JA to occur and "yielded some positive effects of joint attention" (Kasari et al., 2006, p. 616).

Treatment with Robots

A relatively new approach to intervention with children with autism is the use of robots within treatment sessions. Recent research has shown evidence that children with autism find robots interesting (Goodrich, Colton, Brinton, & Fujiki, 2011). Scassellati (n.d) found that while typical developing children were initially attracted to robots but tended to quickly lose interest in them, children with autism attended greatly to the robot. Children with autism showed a high degree of motivation and engagement while working with the robot and would consistently attend to the robot, regardless of whether or not the robot was responding to them. Children with autism exhibited JA behaviors with the robot, including smiling at the robot, making eye contact, and vocalizing.

Current research suggests that children with autism may respond well to social interaction with robots because they are inanimate objects which can provide a safe and relaxing environment for interaction (Miyamoto, Lee, Fujii, & Okada, 2005). The use of a robot can also make interactions more predictable and less intimidating, create consistency in a routine, and allow children with autism to be more focused on the interaction because of the limited number of ways the robot can communicate and interact with them (Blomgren & Tenggren, n.d.). Due to the interest that children with autism show in robots, robots have been presented as a potential tool for intervention targeting social engagement. Robots can provide a simplified social environment for children with autism and gradually add complexity to the social interactions as the child improves in various social behaviors (Goldsmith & LeBlanc, 2004). Robots can also be used as a tool to teach social interaction skills to children with autism through turn-taking and imitation games (Goldsmith & LeBlanc, 2004). The current focus of utilizing robots within intervention emphasizes the use of robots as "mediators and as objects of shared attention [to] encourage interaction with peers and adults" (Goldsmith & LeBlanc, 2004, p. 172).

Although several researchers have reported notable gains in JA using robots with children with autism (Goldsmith & LeBlanc, 2004; Miyamoto et al., 2005; Robins, Dickerson, Stribling, & Dautenhahn, 2004), a serious limitation to this work has been the failure of these gains to generalize to humans. To date, few researchers have reported that gains in JA achieved between children with autism and robots have carried over to the interactions of those children with other humans (Scassellati, 2008).

In 2010, a multi-disciplinary team of researchers at Brigham Young University conducted a pilot study which investigated the use of a humanoid robot in a 15-week intervention program with two children with ASD (Acerson, 2011; Goodrich, et al., 2011; Hansen, 2011; Richey, 2011). A defining characteristic of this intervention was that the child's exposure to the robot was "low dose" in the sense that it comprised only a short segment of the child's overall treatment time (approximately 10 min of a 50 min session). The low dose application distinguished the interventions from other applications of robots with children with autism. The pre- and post-treatment sessions without the robot were analyzed for social engagement behaviors. Results suggested 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 BYU research team initiated a more comprehensive investigation to further determine if the previously observed findings could be replicated with other children with autism. The current study examined one aspect of this larger project. Several behaviors indicative of social engagement (eye contact, symbolic play, initiating engagement, language, & reciprocal action) were analyzed in pre- and post-intervention assessment sessions. Specifically, 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 familiar adult interaction?
2. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing symbolic play in a familiar adult interaction?
3. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing initiating engagement in a familiar adult interaction?
4. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing language in a familiar adult interaction?
5. Does low-dose involvement of a humanoid robot in social engagement intervention aid in increasing reciprocal action in a familiar adult interaction?

Method

Participants

Four children diagnosed with severe autism participated in the intervention study. Each child exhibited severe deficits in social and communicative functioning, including minimal joint attention behaviors, and severe language impairment. An audiological assessment was also administered to each child by the audiologist at the Brigham Young University Speech and Language Clinic. Each child had typical hearing status. Ethnographic interviews were conducted with the mother of each participant to provide demographic and descriptive data of each child and their demonstrated behaviors. The following information was obtained through parent report and direct observation.

Participant 1, AH. AH was a 4:11 (year: month) year-old female. She lived with both parents who were each employed. AH had no siblings and English was the primary language spoken in the home. At the time of participation in the study, AH was currently enrolled in a developmental preschool for children diagnosed with autism.

AH was nonverbal at the time of the study. She showed limited sound play as well as minimal verbal word approximations. AH could imitate signs following a visual prompt from her mother but would not sign spontaneously. AH demonstrated repetitive motoric patterns and was emotionally labile. When AH was dis-regulated, she would cry or hug those around her. At times when AH would attempt to express her wants and needs and was not understood, she would cry in an attempt to communicate. AH displayed splinter skills in symbolic play, exhibiting limited symbolic play skills with select objects. AH made attempts at initiating behavior requests and would use the people around her as tools to get what she wanted.

Participant 2, LS. LS was a 9:1-year-old male. He lived with both parents and had four siblings ages 11, 14, 16, and 18. His father was employed, while his mother worked in the home. English was the primary language spoken in the home. LS was born in Japan and lived there until 4:5 years old. LS had previously attended a developmental preschool for children diagnosed with autism and at the time of participation in the study, he was enrolled in a self-contained autism unit at an elementary school.

LS displayed limited intentional communication. According to parent report, LS had an expressive vocabulary of approximately 150 words. LS used the PECs symbol system and was moderately echolalic. LS demonstrated difficulty with emotional regulation. He was sensitive to sounds and tactile input and would become over-stimulated easily. His response to this emotional disregulation was typically exhibited through self-injurious behaviors and aggressive actions towards others. LS also displayed repetitive motoric patterns. LS would participate in interactions, but was not engaged.

Participant 3, KR. KR was a 8:1-year-old female. KR lived with both parents and had 5 siblings, ages 3, 5, 9, 19, and 23. Her father was employed, while her mother worked in the home. English was the primary language spoken in the home. KR had previously attended a developmental preschool for children diagnosed with autism. At the time of the study, KR was currently enrolled in a self-contained autism unit operating at her elementary school.

KR demonstrated limited communication abilities. She approximated language through the use of babbling, jargon, and imitation of normal prosodic patterns. KR had an expressive vocabulary of 4-5 real words. When experiencing frustration, KR would yell and throw objects. KR would emotionally regulate through the use of sensory stimulation behaviors such as hand-biting and focused attention on specific favorite objects. KR exhibited moderate attempts to interact with others using positive affect and eye contact.

Participant 4, LR. LR was a 5:5-year-old male. LR lived with both parents and had 5 siblings, ages 3, 8, 9, 19, and 23. His father was employed, while his mother worked in the home. English was the primary language spoken in the home. At the time of participation in the study, LR was attending a developmental preschool for children diagnosed with autism.

LR was nonverbal at the time of the study. He demonstrated auditory stimulation through sound play with flat prosody. LR exhibited repetitive motoric patterns such as hand flapping and tapping objects together. LR had a short attention span during activities. During times of frustration, LR would leave the interaction and lay in the corner of the room. He gestured to initiate behavior requests regarded items he wanted. LR would interact through displays of moderate eye contact and positive affect, typically laughing and smiling.

Robot: Troy

The humanoid robot, referred to as Troy, was created by a team consisting of graduate students from the Mechanical Engineering and Computer Science departments at Brigham Young University. Troy was a 15-lb upper body humanoid robot designed to be the same size as an average 4-year old child: 25 inches (63.5 cm) tall with arms 12 inches (30.5 cm) in length (Ricks, 2010, Richey, 2011). The body of the robot consisted of a trunk, base, 2, arms, neck, and head. The 7 inch (17.8 cm) computer screen which served as Troy's head had a simple face displayed on the screen, with 3 options of emotional expressions – happy, sad, and neutral (Hansen, 2011).

Using a program developed by students in the computer science department specifically for the robot, clinicians pre-programmed the robot's actions, sounds, and facial combinations to be used in treatment sessions. Troy was programmed with sound clips including customized greetings for each child, familiar children's songs, and positive (i.e., "*Yipee!*") and negative (i.e., "*Whoops!*") affective expressions. Troy's arms were programmed with actions such as waving, pushing forward, tapping multiple times, and raising arms upward, etc. For further information regarding the robot, its programming, and functions, see Ricks (2010), Acerson (2011), Hansen (2011), and Richey (2011).

Each session was recorded on the stationary clinic video cameras mounted in the corner of the clinic room. In addition, a student volunteer was present in the clinic room during each session, operating a hand-held video camera. The hand-held camera kept a continuous view of the participant's face. This was done in an effort to increase visibility of the child's face in recordings to determine the presence or lack of facial expression and eye contact throughout the session for the purposes of coding these behaviors.

Procedure

A single-subject multiple baseline design was used for the study. Each participant was seen for intervention for two 50-minute sessions each week. All baseline, intervention, and follow-up sessions were administered at the Brigham Young University Speech and Language Clinic. Each participant was randomly assigned to receive 3, 4, 5, or 6 baseline sessions. Concluding each child's participation in baseline sessions, traditional treatment was implemented. The 20 intervention sessions that followed baseline consisted of traditional intervention. Approximately 10 minutes of each therapy session involved the robot. For a complete summary of the number of various treatment sessions delivered to each participant, see Table 1.

Baseline and Follow-up Measures. Each child in this study participated in pre-treatment measures which assessed their baseline levels of social engagement skills. During these baseline sessions, four interactions took place: a parent and child interaction, a familiar adult interaction, a less-familiar adult interaction, and a triadic interaction. See Appendix B for a complete listing of the protocol measures for baseline sessions. For the purposes of this study, the familiar adult interaction was analyzed for social engagement behaviors.

Table 1

Number of Sessions Assigned to Each Participant

	Participant 1	Participant 2	Participant 3	Participant 4
Baseline	3	4	5	6
Traditional Treatment	3	4	5	6
Traditional Treatment with Robot	17	16	15	14
Follow-Up	3	3	3	3

The familiar adult interaction consisted of the child interacting with the graduate clinician who was assigned to work with them. This interaction typically lasted for 10 to15 minutes. The graduate clinician randomly presented the following items to the child: baby doll with blanket, baby doll with food, car, ball, and wind-up toys. The clinician would also sing two songs, *Popcorn Popping on the Apricot* Tree and *The Eensy Weensy Spider*. Each item was presented to the child three separate times. After initially presenting the child with the item, the graduate clinician would wait for 20 seconds to allow the child adequate time to respond. If the child responded appropriately to the play items, the clinician would attempt to expand the interaction with the child. However, if the child did not respond appropriately after the clinician presented the item a total of three times, the clinician would introduce the next activity.

The baseline measures were repeated at the conclusion of the 20 intervention sessions. Each child participated in 3 follow-up sessions with the same measures that were used in the baseline sessions.

Intervention Procedures. Intervention was provided by four graduate student clinicians (one for each of the four clients). The four clinicians also interacted with each of the clients in the role of assistant clinician. The graduate clinicians were supervised by the Clinic Director of the BYU Speech and Language Clinic to ensure the quality of treatment provided.

Traditional Treatment. After each participant completed their allotted amount of baseline measures, they participated in traditional treatment sessions which did not include the use of the robot. Each individual child participated in the same number of traditional treatment sessions as the number of baseline sessions they had received. Treatment goals for intervention were individualized for the participants and chosen on the basis of areas of deficiency which were identified through assessment and parent report. Intervention was based on the SCERTS model and emphasized social communication, emotional regulation, and transactional support (Prizant, Wetherby, Rubin, & Laurent, 2003). Therapy was delivered in a highly interactive, play based approach. For each participant, traditional treatment focused on their individual goals which targeted increasing social engagement, verbal communication, and symbolic play skills.

Treatment Sessions including the Robot. Upon completion of the allotted amount of traditional treatment sessions, the treatment sessions using the robot were initiated. Each participant attended 50 minute therapy sessions, twice a week. About 40 minutes of the session consisted of intervention techniques which had previously been used during the traditional treatment. During each session, a 10- to 15-minute interaction with Troy was placed at randomized times within the session. The segment of treatment with the robot consisted of a triadic interaction between Troy, the child, the child's mother, and the primary graduate clinician for that child. An assisting graduate clinician was also present during the interaction, sitting behind the child to provide hand-over-hand support and also model appropriate behaviors and responses for the child.

The interaction with Troy began with a greeting taking place between Troy and the child. An exchange which took place during each interaction with the robot included singing and performing accompanying actions to the song as a group. The main portion of the interaction with Troy consisted of a variety of activities chosen by the clinician, which specifically appealed to the child. Activities used during these triadic interactions included manipulating toys like a ball, car, tambourine, bubbles, or engaging in symbolic play like trying on hats, eating food, and fishing. Interactions with Troy highlighted turn-taking, as well as the sharing of both positive and negative affective responses.

Data Analysis

The baseline and follow-up sessions for all participants were analyzed and coded for the purposes of this study. The recordings from both camera views (stationary clinic camera and hand-held camera) were synced using the program Final Cut Pro Express. This allowed both cameras to be viewed side by side for the purposes of coding participant behaviors. The coding system used in this study was developed to measure participant reactions to the clinician's probes.

The coding system specifically focused on social engagement which was divided into categories of: eye contact, symbolic play, initiating engagement, language, and reciprocal action. Each of these categories consisted of specific behaviors that were analyzed and coded for the purposes of the current study. The category of eye contact involved the participant making direct eye contact with the clinician. Symbolic play consisted of the participant manipulating object in such a manner reflecting appropriate symbolic play behaviors. Initiating engagement involved a verbal request for the activity to be performed again or giving items to the clinician independently. The category of language included the participant behavior of signing or speaking about the activity or a topic involving the activity. Reciprocal action included participant behaviors of performing the correct actions of a song, singing along, or returning items to the clinician.

The baseline and follow-up sessions involved several contexts. As noted previously, for the purposes of the current study, only components of the familiar adult interaction which focus on social engagement behaviors will be reported. These social engagement behaviors were calculated and compared between the pre- and post-intervention sessions. Four graduate student clinicians were trained in the analysis system used and inter-judge reliability was established at these percentages for each category of social engagement behaviors: eye contact (93.1%), reciprocal action (96.5%), symbolic play (95.1%), initiating engagement (98.5%), and language (100%). For detailed information on coding and data analysis procedures, including specific coding guidelines, refer to Appendix C (TiLAR Team, 2012).

Results

This study examined the social engagement behaviors of four children with autism who participated in treatment involving low-dose exposures to a humanoid robot. Pre- and post-intervention assessments were conducted and coded for social engagement behaviors. The current study examined the pre- and post-intervention sessions for social engagement behaviors during a portion of the familiar adult interaction.

The following is a summary of each participant's performance in the pre- and post-intervention sessions during the familiar adult interactions using the following materials/probes: baby with blanket, baby with food, and singing two songs. A description of each participant's social engagement behaviors is provided. Clinical observations are added to supplement the child's behavior to the probes during the pre- and post-intervention sessions.

AH's Performance

Baseline and follow-up testing. AH participated in three pre-intervention sessions and three post-intervention sessions. Results of AH's social engagement behaviors interacting with a familiar adult in each pre- and post-intervention session is outlined in Figure 1 (and Table 1 in Appendix D).

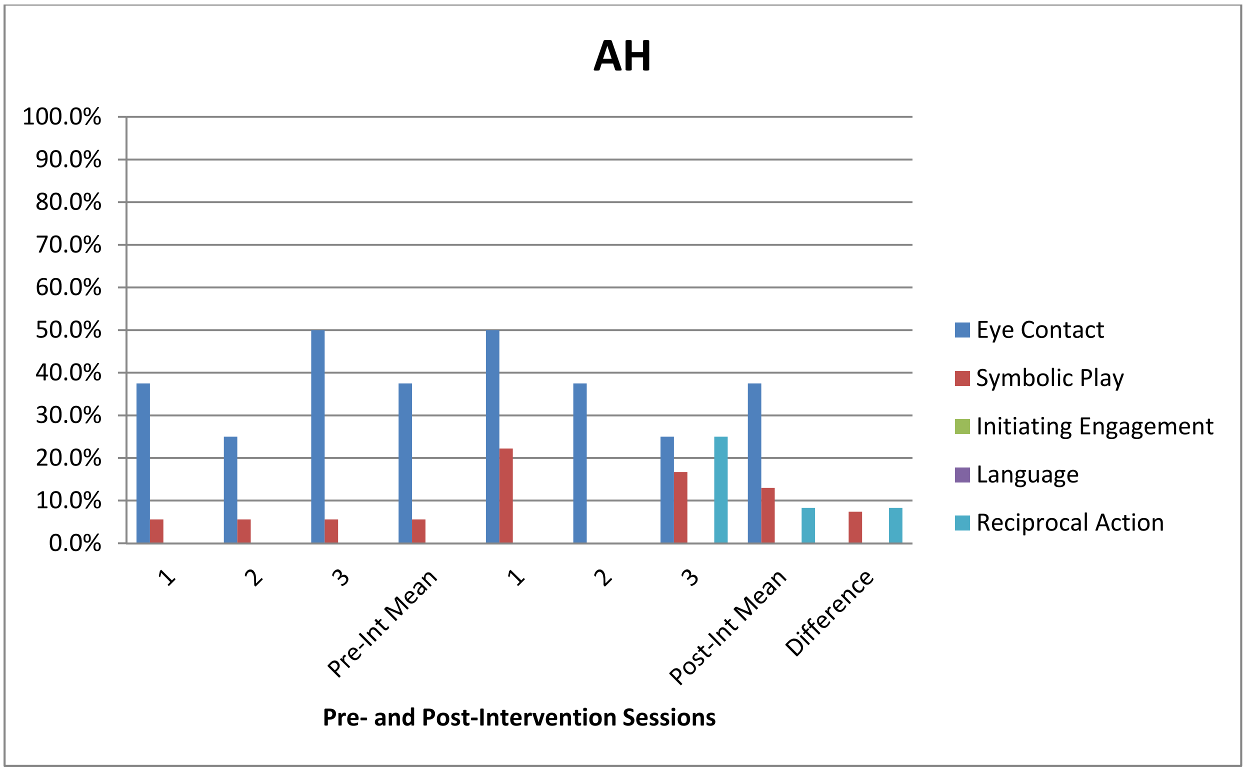

Figure 1. Participant 1, AH – Social engagement behaviors in a familiar adult interaction.

AH's performance was inconsistent across sessions. AH showed an overall increase of 7.4% in symbolic play and an increase of 8.3% in reciprocal action. There was little or no change demonstrated in eye contact, initiating engagement, and language.

Clinical observation. Clinical observations revealed that AH often played with a baby doll. This appropriate play behavior (e.g., feeding the baby doll with a bottle) did not extend to other toys or objects in a similar manner, however, and could be considered as a splinter skill. This behavior was observed in both the pre- and post-assessment sessions, and may have influenced her performance during the probes.

Clinical observations also noted AH made more attempts at verbal approximations over the course of the study; however, no true words were produced. For example, the clinician reported that AH made attempts at producing her name as well as the beginning sound for the word "juice". These clinical observations are inconsistent with the language results represented in the pre- and post-intervention data.

LS's Performance

Baseline and follow-up testing. LS participated in four pre-intervention sessions and three post-intervention sessions. The results of LS's social engagement behaviors during a familiar adult interaction for the pre- and post-intervention sessions are reported in Figure 2 (and Table 2 in Appendix D).

LS demonstrated substantial increases in select social engagement behaviors. He demonstrated a 35% increase in reciprocal action and a 21.9% overall increase in eye contact. As indicated in Figure 2, LS's eye contact was variable in pre-intervention sessions and consistent in post-intervention sessions. There were no changes in language and initiating engagement and a 0.5% increase in symbolic play.

Clinical observation. During the post-intervention sessions, LS did not play in a typical manner with the baby doll, but would pick up the baby and focus intently on its face. This behavior represented a change from baseline where LS interacted with the baby by removing the

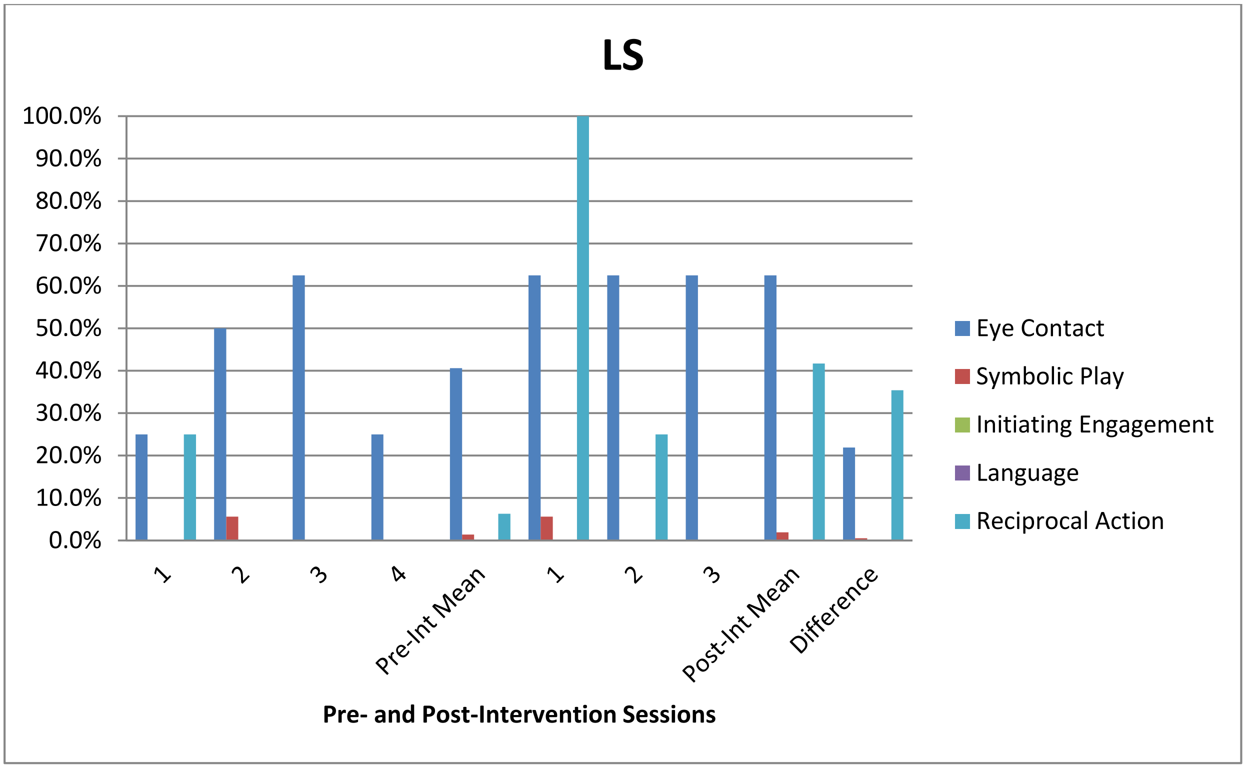

Figure 2. Participant 2, LS – Social engagement behaviors in a familiar adult interaction

doll's head, flinging the doll around, or disregarding the doll entirely. Although a change was noted clinically, this was inconsistent with the results of the probes. This difference stemmed from coding rules which provided specific guidelines for what could be counted as appropriate interactions with the baby doll. Guidelines for appropriate play with the baby doll included: cuddling, hugging, kissing or rocking the baby, wrapping the baby in a blanket, and feeding the baby with a bottle or a spoon. LS's actions towards the baby did not conform to these guidelines, and thus were not counted as appropriate.

LS also showed improvement in his ability to emotionally regulate, through both self and mutual regulation. For example, as the study progressed, LS's clinician became more skilled in using techniques to help LS to emotionally regulate. Clinical observations also noted an improvement in eye contact paired with reciprocal action, which was consistent with the results.

KR's Performance

Baseline and follow-up testing. KR participated in five pre-intervention sessions and three post-intervention sessions. Results for KR's social engagement behaviors in a familiar adult interaction for pre- and post-intervention sessions are outlined in Figure 3 (and Table 3 in Appendix D).

KR's performance showed some improvements in social engagement behaviors. Eye contact was inconsistent during pre-intervention sessions but became more consistent during post-intervention sessions, increasing by 30.8%. KR also showed an 8.3% increase in reciprocal action. There was little or no change in symbolic play, initiating engagement or language behaviors.

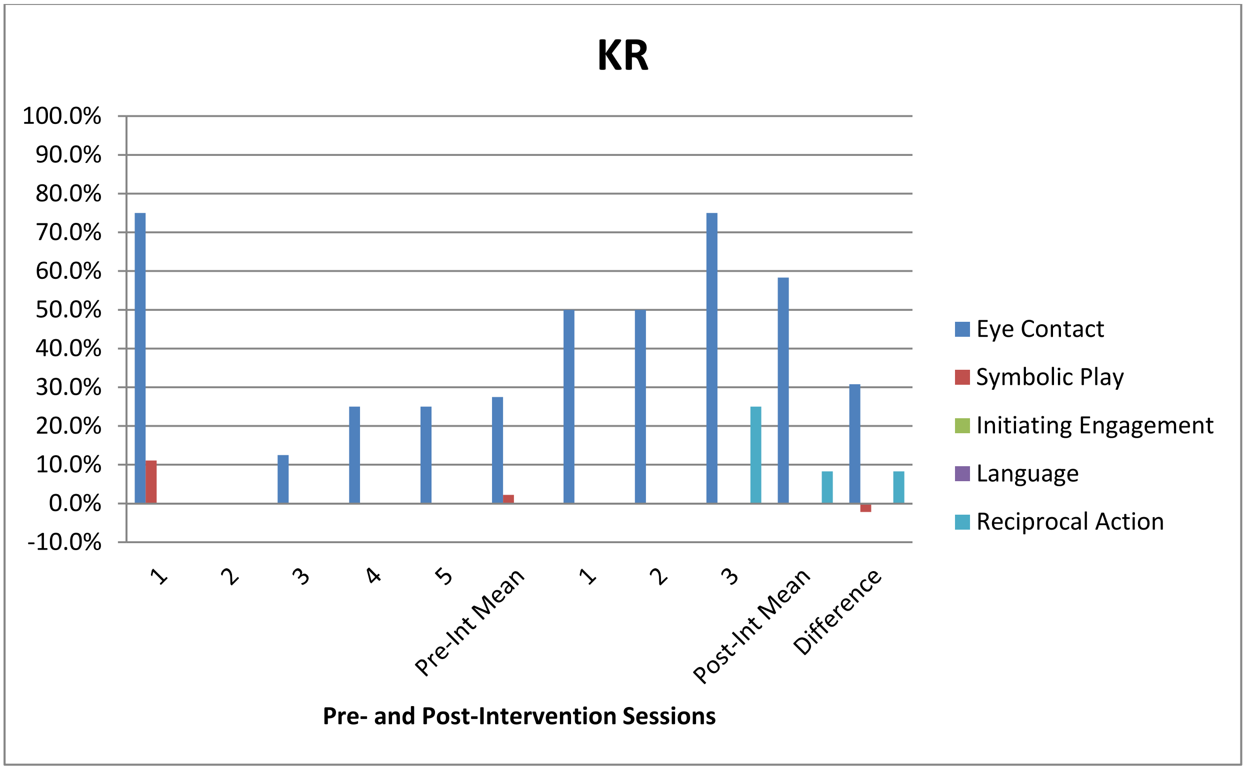

Figure 3. Participant 3, KR – Social engagement behaviors in a familiar adult interaction

Clinical observation. KR's performance in some pre- and post-intervention sessions was inconsistent due to her health and/or ability to regulate. KR showed increased eye contact during interactions with the familiar adult, in contrast to interactions with unfamiliar adults. During the post-intervention sessions, it was noted that KR would throw the majority of materials presented during the probes, which was consistent with the results and lack of change in the data for initiating engagement and symbolic play. KR made more attempts to vocalize, but did not produce true words, which was consistent with the results for language.

LR's Performance

Baseline and follow-up testing. LR participated in six pre-invention sessions and three post-intervention sessions. LR's results for social engagement behaviors in a familiar adult interaction during pre- and post-intervention sessions are reported in Figure 4 (and Table 4 in Appendix D).

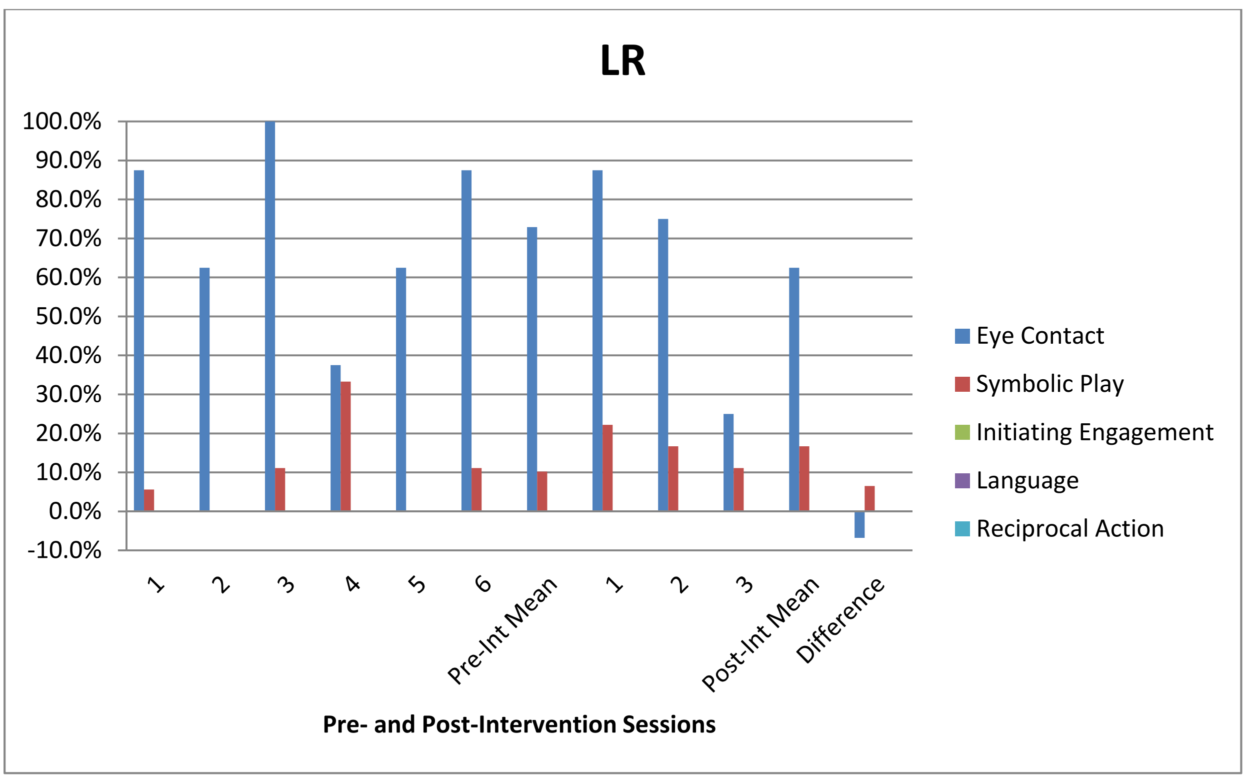

Figure 4. Participant 4, LR – Social engagement behaviors in a familiar adult interaction

LR's eye contact decreased overall by 6.8% from the pre- to post-intervention assessment. In considering these data, however, it is important to note the marked decrease in eye contact exhibited during the fourth pre-intervention session and the third post-intervention session, reflecting a potential for inconsistent performance in this behavior. Despite variable performance, LR's symbolic play behaviors showed a small increase of 6.5% during the post-intervention sessions. LR demonstrated no change in the social engagement behaviors of initiating engagement, language, and reciprocal action.

Clinical observations. Based on clinical observations in the post-intervention sessions, LR demonstrated more reciprocal actions paired with eye contact outside of the specific probes used for social engagement measurement. Clinical impressions suggested that LR demonstrated increased eye contact during interactions, which was inconsistent with the results reported in pre- and post-testing. It appeared that LR became increasingly frustrated with the tasks during the last post-intervention session and this likely resulted in the overall decreased eye contact during that session. Clinical observations relating to initiating engagement, language, and reciprocal action during the specific familiar adult probes were consistent with the results from the pre- and post-intervention assessments.

Discussion

This study focused on the pre- and post-intervention assessments of four children with autism who participated in a treatment program using a humanoid robot during therapy sessions. The current study focused on the social engagement behaviors demonstrated during the pre- and post-intervention assessments for each participant in interactions with a familiar adult.

Participants' Response to the Intervention

Participants' responses to the probes of baby with blanket, baby with food, and singing during the familiar adult interaction were highly variable. As might be expected, some children responded more favorably to the intervention than others, with production of the various social engagement behaviors showing a range of outcomes from pre- to post-intervention testing. Each of the behaviors examined is considered as follows.

Reciprocal action was probed as the children participated in a singing activity in which the familiar adult sang a song. Three of the participants demonstrated improvements in reciprocal action. These increases were encouraging because the interactions with Troy during the intervention sessions were heavily focused on reciprocal actions, specifically involving turn-taking and singing. Other interactional behaviors may have showed little or no change (e.g., symbolic play, initiating engagement) because the intervention with the robot did not directly target these behaviors. Of the four participants, LS showed the greatest improvement in reciprocal action. His gains may have been facilitated by his slightly higher language abilities, which allowed him to sing along with the familiar adult. His level of interest in music may have also influenced his marked improvements in this area.

Two participants showed improvement in eye contact, one showed no change, and one decreased in this behavior. KR showed a large improvement in eye contact. During the post-intervention assessment with the familiar adult, KR generally showed a lack of interest in interacting with the materials presented during the probes and demonstrated inappropriate interaction with the probes. She would pick up the materials presented and throw them towards the corner of the room or at the clinician. However, KR appeared to show a desire to engage with the clinician without interacting with the probes, and did this through her eye contact with the clinician. KR's improvement in eye contact may also be attributed to her increased familiarity with her clinician. For LR, who produced an overall decrease in eye contact behaviors, it is important to note the large decrease in eye contact in the third follow-up session. This marked decrease may have been due to the participant's frustration with and lack of interest in the probes. LR participated in the highest number of baseline and follow-up sessions, which may have negatively influenced his behavior.

Language behaviors did not change for any of the participants. Given overall developmental level, as well as prior history of intervention, notable change was not expected in spoken language within the short time period in which the study was conducted. However, language was included in the analysis system to provide a comprehensive look at each child's response to the intervention.

None of the participants showed improvement in initiating engagement during the probes analyzed for the familiar adult interaction. To some extent this outcome was expected because the probes used in the pre- and post-intervention assessments focused on facilitating responding to joint engagement rather than initiating joint engagement. Initiating joint engagement is an important aspect of overall social engagement (Bruinsma et al. 2004), however, and merited inclusion in the analysis system for this reason.

Three participants showed small improvement in responding to engagement in the context of symbolic play, which may be attributed to the interactions with the robot. During interactions with Troy, these behaviors were often targeted through play routines where each person in the interaction with Troy would take a turn in a symbolic play routine, such as trying on hats and pretending to eat play food. Improvements in this area of social engagement may have also been influenced by the participant's level of interest in the activity of interacting with the baby doll. For example, AH showed splinter skills in symbolic play at the beginning of the study, which may have provided her with a foundation to build upon during the study.

Limitations and Suggestions for Future Research

In interpreting the results of this study, several limitations should be considered. First, the children were relatively unfamiliar with their clinicians prior to beginning participation in the study. The participants only interacted with their clinician for a few assessment sessions before beginning the baseline measures. Increased familiarity between the clinicians and participants may have enhanced the ability of the clinicians to help the children maintain a better state of emotional regulation, which may have contributed to the observed gains. A related issue has to do with the length of the study. The current investigation was conducted over a relatively short period of time, lasting about three months. A longer intervention period may have produced greater improvements in social engagement behaviors due to extended exposure to intervention with the robot. It would have allowed opportunity for the children to become more familiar with their clinicians and minimized the impact of the developing child-clinician relationship. It would have also helped to account for the fact that as the clinicians worked with the children, they developed specific techniques to help the children better regulate themselves. The increased regulation most likely also contributed to gains in social engagement.

A third limitation was that the analysis system used to code behaviors seen in the pre- and post-intervention assessments followed a strict set of probes and a narrow set of social engagement behaviors. This system was developed to respond to the fact that it was often difficult to interpret the behaviors of the participants. For instance, the actions of smiling and laughing would indicate engagement for typically developing children. However, for KR and LR, these behaviors did not always appear to reflect engagement. Both children smiled frequently but it was often difficult to determine the cause or meaning of the emotion they were exhibiting. AH would smile during times where no external stimulus was present and would show little to no affect in contexts where an affective reaction would typically be anticipated. LS would laugh and make eye contact immediately before and during aggressive actions when he was highly dis-regulated. The analysis system allowed the examiners to reliably code behavior. It was notable, however, that due to the strict nature of the analysis system, some meaningful instances of social engagement were not counted because they occurred outside of the analysis guidelines. A system which could reliably account for a wider range of social engagement behaviors outside of specific probes would be useful in providing a more accurate picture of performance.

Another limitation was that each participant was unique, demonstrating individual needs (e.g., specific health issues) and limitations. To some extent, this individual variation was unavoidable, given the heterogeneity associated with the diagnostic category of autism. Nevertheless, it is important to recognize the impact of individual differences because it has some explanatory power as to why the intervention appeared more effective for specific children. By way of illustration, KR was sick during some of the sessions which resulted in marked differences in her participation. Rather than engaging in the interaction, KR would spend much of the session lying down, even falling asleep on occasion. Another example of how individual factors influenced performance was that the children reacted differently to sensory input. For example, LR would plug his ears and make noises conveying his discomfort when clinicians would introduce noise making toys into the interaction. However, when given a turn to play with these toys, LR would accept the toy and hold the toy very close to his ear while repeatedly making noise with the toy. Other factors which may have influenced participant performance were fatigue and interest in the probes. Additionally, as the study progressed, at least one participant, LR, appeared to lose interest in the probes and materials which were used in the pre- and post-intervention assessments.

One way of addressing this individual variation in future studies would be to use a larger sample of children. With increased sample size, individual variability would have less impact on overall outcomes. Even with a larger sample, however, it will be important to be aware of how individual variability impacts individual performance. Given that children with autism are notoriously heterogeneous, it may never be possible to completely eliminate these differences from an intervention study.

Two final recommendations for future research do not stem from limitations, but from observations made during the study. The first was that all of the children showed interest in the robot. This finding is similar to observations made by a number of other researchers. Examples of participant interest were as follows. LS would request Troy during sessions using his picture schedule and seemed to enjoy the time spent with Troy. LR showed interest in Troy's face and would straighten the robot's arm when it was bent out of the standard position. If this finding is generalizable to other children with autism, it may be possible to include robots in intervention specifically to heighten motivation.

A second observation that may motivate future research was the fact that the robot appeared to serve as an effective regulation tool in enhancing the emotional regulation of some participants. For example, LR's clinician noted that he appeared to be calmer in the portions of the session with Troy, attending better to activities while Troy was present in the room. During the session in which AH was first introduced to Troy, she had been dis-regulated and was continually crying. Once Troy was introduced, AH ceased crying and was able to focus on the interaction taking place with Troy. This observation merits future study to determine if the finding is generalizable to other children. If so, it would be of interest both theoretically and clinically. Further work is needed to determine why robots have this effect as well as how it might best be used to manage behavior.

Conclusion

This study examined the influence of a traditional intervention program enhanced by low doses of interaction with a robot to increase social engagement in four children with autism. Pre- and post-intervention sessions involving interactions with a familiar adult were compared. The most notable gains were seen in three of four participants in the social engagement behavior of reciprocal action. This was encouraging, in that the intervention involving the robot targeted reciprocal activities in a multiple participant interactional format. However, these results are preliminary. Future research in this area of robot intervention should include longer periods of traditional intervention prior to introduction of the robot, increased length of intervention with the robot used in therapy, a comprehensive analysis system, and larger sample size of children.

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Appendix A

Data tables corresponding to Figures 1 through 4

Table 1

Participant 1, AH – Social engagement behaviors in a familiar adult interaction

	Pre-Intervention Sessions			**Pre-Int Mean**	Post-Intervention Sessions			**Post-Int Mean**	**Diff.**
(in %)	1	2	3		1	2	3		
Eye Contact	37.5 (3/8)	25.0 (2/8)	50.0 (4/8)	**37.5 (9/24)**	50.0 (4/8)	37.5 (3/8)	25.0 (2/8)	**37.5 (9/24)**	**0.0**
Symbolic Play	5.6 (1/18)	5.6 (1/18)	5.6 (1/18)	**5.6 (3/54)**	22.2 (4/18)	0.0 (0/18)	16.7 (3/18)	**13.0 (7/54)**	**7.4**
Initiating Engagement	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/24)**	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/24)**	**0.0**
Language	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/18)**	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/18)**	**0.0**
Reciprocal Action	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	**0.0 (0/12)**	0.0 (0/4)	0.0 (0/4)	25.0 (1/4)	**8.3 (1/12)**	**8.3**

Table 2

Participant 2, LS – Social engagement behaviors in a familiar adult interaction

(in %)	Pre-Intervention Sessions 1	2	3	4	Pre-Int Mean	Post-Intervention Sessions 1	2	3	Post-Int Mean	Diff.
Eye Contact	25.0 (2/8)	50.0 (4/8)	62.5 (5/8)	25.0 (2/8)	**40.6 (13/32)**	62.5 (5/8)	62.5 (5/8)	62.5 (5/8)	**62.5 (15/24)**	**21.9**
Symbolic Play	0.0 (0/18)	5.6 (1/18)	0.0 (0/18)	0.0 (0/18)	**1.4 (1/72)**	5.6 (1/18)	0.0 (0/18)	0.0 (0/18)	**1.9 (1/54)**	**0.5**
Initiating Engagement	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/32)**	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/24)**	**0.0**
Language	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/24)**	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/18)**	**0.0**
Reciprocal Action	25.0 (1/4)	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	**6.3 (1/16)**	100.0 (4/4)	25.0 (1/4)	0.0 (0/4)	**41.7 (5/12)**	**35.4**

Table 3

Participant 3, KR – Social engagement behaviors in a familiar adult interaction

	Pre-Intervention Sessions					**Pre-Int Mean**	Post-Intervention Sessions			**Post-Int Mean**	**Diff.**
(in %)	1	2	3	4	5		1	2	3		
Eye Contact	75.0 (6/8)	0.0 (0/8)	12.5 (1/8)	25.0 (2/8)	25.0 (2/8)	**27.5 (11/40)**	50.0 (4/8)	50.0 (4/8)	75.0 (6/8)	**58.3 (14/24)**	**30.8**
Symbolic Play	11.1 (2/18)	0.0 (0/18)	0.0 (0/18)	0.0 (0/18)	0.0 (0/18)	**2.2 (2/90)**	0.0 (0/18)	0.0 (0/18)	0.0 (0/18)	**0.0 (0/54)**	**-2.2**
Initiating Engagement	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/40)**	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/8)**	**0.0**
Language	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/30)**	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/18)**	**0.0**
Reciprocal Action	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	**0.0 (0/20)**	0.0 (0/4)	0.0 (0/4)	25.0 (1/4)	**8.3 (1/12)**	**8.3**

Table 4

Participant 4, LR – Social engagement behaviors in a familiar adult interaction

	Pre-Intervention Sessions						**Pre-Int Mean**	Post-Intervention Sessions			**Post-Int Mean**	**Diff.**
(in %)	1	2	3	4	5	6		1	2	3		
Eye Contact	87.5 (7/8)	62.5 (5/8)	100.0 (8/8)	37.5 (3/8)	62.5 (5/8)	87.5 (7/8)	**72.9 (35/48)**	87.5 (7/8)	75.0 (6/8)	25.0 (2/8)	**62.5 (15/24)**	**-6.8**
Symbolic Play	5.6 (1/18)	0.0 (0/18)	11.1 (2/18)	33.3 (6/18)	0.0 (0/18)	11.1 (2/18)	**10.2 (11/108)**	22.2 (4/18)	16.7 (3/18)	11.1 (2/18)	**16.7 (9/54)**	**6.5**
Initiating Engagement	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/48)**	0.0 (0/8)	0.0 (0/8)	0.0 (0/8)	**0.0 (0/24)**	**0.0**
Language	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/36)**	0.0 (0/6)	0.0 (0/6)	0.0 (0/6)	**0.0 (0/18)**	**0.0**
Reciprocal Action	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	**0.0 (0/24)**	0.0 (0/4)	0.0 (0/4)	0.0 (0/4)	**0.0 (0/12)**	**0.0**

Appendix B

Annotated Bibliography

Acerson, A.K. (2011). The effects of the use of a robot during intervention on joint attention in children with autism (Unpublished master's thesis). Brigham Young University, Provo, Utah.

Purpose of the study: Acerson evaluated the pre- and post-assessments of two children with autism, which were conducted after intervention was provided using a humanoid robot, Troy. The treatment provided with the robot was considered low-dose, meaning the interactions with the robot were about 10 minutes in length.

Method:
Participants: The participants were two children with ASD. Both participants had previously attended the Brigham Young University Clinic for a year before enrollment in the study. During the previous intervention, neither participant had made notable progress in social engagement behaviors or joint attention.

Procedures/Assessment Instrumentation: The two interactions evaluated in this study were: child-parent play assessment and child-clinician play assessment. During interventions with the participants, 10-15 minute triadic interactions took place with the robot across 16 sessions. The pre- and post-intervention assessments were coded for specific social engagement behaviors. Other clinical observations were noted which were not captured through the data analysis system.

Results: During the post-intervention assessments, one participant demonstrated notable gains in social engagement behaviors. The second participant increased in some social engagement behaviors and decreased in other behaviors. The clinical observations reported suggested increased social engagement behaviors in both participants.

Conclusions: Results were substantial for one participant, while variable for the other participant. Results may have been influenced by parent interaction styles, as well as age and behavioral tendencies of the participants.

Relevance to the current work: The current study is a more comprehensive investigation of this treatment approach.

American Psychiatric Association. (2000). ***Diagnostic and statistical manual of mental disorders – Fourth edition – Text revision*** **(4th text rev. ed.). Washington, D.C.: American Psychiatric Association.**

Purpose of the work: This chapter discusses the disorders first diagnosed in infancy or childhood. Specifically, developmental, learning, and pervasive developmental disorders are described.

Summary: Autism is a pervasive developmental disorder. The diagnostic criteria for autism includes: impairment in social interaction, language use in social communication, and symbolic play. Children with autism typically demonstrate a lack in spontaneously seeking to share interests or enjoyment with other people. Communication impairments manifest in children with autism through both verbal and nonverbal skills. Typically individuals with autism show restricted and repetitive patterns in their behavior, activities, and interests. The onset of autism occurs in children prior to the age of 3. Additional pervasive developmental disorders including Rett's Disorder, Childhood Disintegrative Disorder, Asperger's Disorder, and Pervasive Developmental Disorder Not Otherwise Specified are described in the chapter.

Relevance to the current work: This chapter provides the definition, diagnostic criteria, and characteristics of autism disorder.

Blackwell, J. (2001). Clinical practice guideline: Screening and diagnosing autism. In J. Goolsby (Ed.) *Journal of the American Academy of Nurse Practitioners, 13*(12), 534-536.

Purpose of the work: This article reviewed procedures for the screening and diagnosing of autism. A scientific and clinically relevant identification system is needed to improve the process of diagnosing children with autism.

Summary: An identification system developed by a panel of members from the American Academy of Neurology (AAN) was reviewed. Two levels of investigation were identified. The first level of "Routine Developmental Surveillance" identifies children who are at risk for developmental delays. All children who fail a routine developmental screening would then be specifically screened for autism. The second level, "Diagnosis and Evaluation of Autism", requires an experienced clinician in the field of autism to make the diagnosis. For the children identified on the first level, a more extensive assessment is performed, to differentiate between autism and any other developmental disorders.

Conclusions: The author recommended that healthcare providers need to increase their knowledge regarding autism. This will improve the early diagnosis, implementation of intervention, and coordination of appropriate care for children with autism.

Relevance to the current work: This article describes the early identifying characteristics of autism.

Blomgren, T., & Tenggren, (n.d.). Robots as an instrument for (re)habilitation of autistic children. Retrieved from http://webzone.k3.mah.se/k3tobl/port/doc/fish.doc

Purpose of the work: This article discussed the advantages as well as difficulties of using a robot within therapy for children with autism.

Summary: The advantages of using a robot within therapy were discussed. First, children with autism may find a robot less intimidating to interact with. Second, a robot can interact in a more predictable manner, which allows the child to feel more comfortable in the interaction. Third, a robot's communication is limited and simplified, which simplifies the amount of information the child must process during the interaction. Fourth, previous studies have shown that children with disabilities enjoy working with computers and technology.

The robot prototype which they developed was also discussed. The robot was designed to show basic emotions through facial expressions and sounds. The child was prompted to identify what emotion the robot was expressing by touching an image on the robot. If the child was right, the robot rewarded him/her. The researchers developed a robot which had a replaceable textile skin and was tough enough to be handled by the child. Using bright lights or colors in the robot's design, which might distract a child with autism, were avoided. The intention of the researchers was for the robot to be used within a controlled environment under the supervision of professionals.

Conclusions: The authors described the advantages of using a robot within therapy for children with autism. They also discussed the challenges with developing and designing a robot appropriate for use within therapy.

Relevance to the current work: The study provided information to consider in designing a robot and implementing the robot within therapy. The study also provided the rationale and advantages for using robots in therapy with children with autism.

Bruinsma, Y., Koegel, R. L., & Koegel, L. K. (2004). Joint attention and children with autism: A review of the literature. *Mental Retardation and Developmental Disabilities Research Reviews*, 10(3), 169-175. doi:10.1002/mrdd.20036

Purpose of the work: Bruinsma et al. reviewed the current literature regarding the joint attention skills of children with autism. The authors focused specifically on the forms and functions of initiating joint attention (IJA).

Summary: Research suggests that the development of IJA is critical to early social development and is the foundation for acquiring language. Children with autism have been shown to have a deficit in IJA behaviors, with their greatest difficulty of joint attention being the ability to make eye contact. Studies were reviewed in which children with autism demonstrated a decreased frequency and use of eye contact. Research has shown that this frequency and duration of eye contact was one of the best predictors of a diagnosis of autism. Children with autism typically exhibit less eye contact to share engagement and enjoyment during their interactions with others.

The types of communicative acts most often used by typical children are: behavior regulation, social interaction, and joint attention. However, children with autism primarily used the communicative act of behavior regulation, for requesting and protesting, rather than engaging in social communication. Research has shown an important relationship between a child's lexicon and the amount of time they have spent in joint attention episodes.

Conclusions: For children with autism, the joint attention skills needed for intentional communication are usually delayed or missing. These joint attention skills may be a prerequisite for development of intentional communication, which could explain the delays in language development observed in these children.

Relevance to the current work: This article described the development of joint attention and how it affects development, both in typical children and children with autism.

Goldsmith, T. R., & LeBlanc, L. A. (2004) Use of technology in interventions for children with autism. ***Journal of Early and Intensive Behavior Intervention,*** **1(2), 166-174.**

Purpose of the work: Goldsmith and LeBlanc reviewed technology-based interventions for children with autism. The focus was on technologies which are used as a temporary instructional aid and then removed once the goal or behavior has been met for the child.

Summary: The authors discussed five types of technological devices for temporary use in intervention: tactile and auditory prompting devices, video, computer, virtual reality, and robots.

First, tactile and auditory prompts are used to prompt children with autism. A second person must be in close proximity to deliver the prompt to the child. Second, video technology is one of the most used and readily available technologies for instructing children with autism. Video is used as a tool for modeling appropriate social behaviors and providing children with autism feedback on their own behaviors. Third, computers have been used to teach a variety of skills to children with autism. Some important skills include: recognizing and predicting emotions, improving vocabulary, improving problem solving, enhancing vocal imitation, and improving problem solving and social skills. Fourth, virtual reality technology has been used to provide children with autism a "three dimensional, computer-generated world in which people can behave and encounter responses to their behavior" (p. 171). Fifth, robots have been used in therapy for children with autism to allow for a simplified social environment in which children can practice various social behaviors. Through interactions with robots, children can learn basic social interaction skills using turn-taking and imitation.

Conclusions: Various technologies have been found to have positive effects in intervention for children with autism. The authors discussed that the next focus of research needs to address whether these technologies are efficacious, cost-effective, or more enjoyable than traditional interventions, however.

Relevance to the current work: This article addressed the potential uses for socially assistive robots during intervention with children with autism.

Goodrich, M. A., Colton, M. B., Brinton, B., & Fujiki, M. (2011). ***A case for low-dose robotics in autism therapy*****. Proceeding of the ACM/IEEE ARS International Conference on Human-Robot Interaction Lausanne, Switzerland.**

Purpose of the study: The authors describe how a humanoid robot can be used in a low-dose therapy approach to promote generalized social engagement behaviors in child-human interactions.

Method:
Participants: Two children with ASD participated in robot-mediated triadic interactions between the child, robot, and clinician for 10 minutes of a 50-min therapy session across 16 sessions.

Procedures/Assessment Instrumentation: Social engagement behaviors were coded and compared from pre-trial and post-trial assessments. During each assessment, the child participated in an interaction with a familiar adult, an unfamiliar adult, and a triadic interaction with two clinicians.

Results: Both participants showed an increase in pro-social interactions during the post-trial assessments.

Conclusions: A future study beginning in January 2011 will be conducted with a 14-week staggered start trial involving four children. The staggered start will provide a way to measure the change in participant behaviors from traditional therapy to the low-dose robot therapy provided.

Relevance to the current work: The results from this study were promising and provided a rationale for conducting the current study.

Hansen, M. (2011). *Intervention for children with autism spectrum disorder using assistive robotics: Effects on triadic interaction and interaction with unfamiliar adult* (Unpublished master's thesis) Brigham Young University, Provo, Utah.

Purpose of the study: Hansen evaluated effects of intervention that included a humanoid robot, Troy, with two children with autism. The treatment provided with the robot was considered low-dose, meaning the interactions with the robot were about 10 minutes in length.

Method:
Participants: Two children with ASD participated in the study. Both participants attended the Brigham Young University Clinic for a year before enrollment in the study. During the previous intervention, neither participant had made notable progress in social engagement behaviors.

Procedures/Assessment Instrumentation: The two interactions evaluated in this study were: interaction with two adults and interaction with an unfamiliar adult. Triadic interactions lasting 10-15 minutes took place with the robot across 16 sessions. The pre- and post-intervention assessments were coded for specific social engagement behaviors.

Results: Both participants demonstrated improvements in social engagement behaviors during the post-intervention assessments. One participant showed a more substantial increase in social engagement behaviors.

Conclusions: The results of this study were substantial for one participant, while variable for the other participant. Results may have been influenced by parent interaction styles, as well as age and behavioral tendencies of the participants.

Relevance to the current work: The current study is a more comprehensive investigation of this treatment approach.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young children with autism: A randomized controlled intervention study. *Journal of Child Psychology Psychiatry, 47*(6), 611-620. doi: 10.1111/j.1469-7610.2005.01567.x

Purpose of the study: This study examined the effectiveness of targeting joint attention and symbolic play in interventions for children with autism.

Method:
Participants: Fifty-eight children between the ages of 3 and 4 who were diagnosed with autism participated in the study. All participants were selected from an early intervention program in which they were enrolled.

Procedures/Assessment Instrumentation: All participants were randomly assigned to one of three groups: joint attention intervention, symbolic play intervention, or the control group. Interventions were conducted with all participants for 30 minutes daily for 5-6 weeks. Pre- and post assessments were performed by independent clinical testers who were not associated with this study. The assessments were recorded and later coded for joint attention and play variables.

Results: Children in the joint attention intervention group demonstrated improvement in their responsiveness to engagement and initiation of joint attention. Children in the symbol play intervention group showed more diverse types and increased amounts of symbolic play.

Conclusions: The study provided promising results regarding the generalization of joint attention and play skills which are taught through intervention for children with autism.

Relevance to the current work: This article provided efficacy for targeting social engagement through joint attention in treatment for children with autism.

Miyamoto, E., Lee, M., Fujii, H., & Okada, M. (2005). How can robots facilitate social interaction of children with autism?: Possible implications for educational environments. Retrieved from: http://www.lucs.lu.se/LUCS/123/Miyamoto.pdf

Purpose of the study: The authors conducted study to examine the social interaction between children with autism and a robot.

Method:
Participants: Five children with autism participated in five sessions with the robot lasting 5-10 minutes across 5 months.

Procedures/Assessment Instrumentation: Two experimental environments were designed with a robot and some blocks on a table. In the first behavioral task, the robot would say simple phrases to the child. In later sessions, the behavioral task was modified and the robot would act intentionally without speaking to the child by pushing or bringing objects and dropping them from the table.

Results: One child interacted mostly with their teacher but also with the robot. Two children did not interact with the robot, while the remaining two children interacted with the robot. The two children who interacted with the robot showed developmental changes and showed more varied interactions with the robot.

Conclusions: From their results, the authors suggest that robots can communicate socially with children with autism. However, further research is needed to support this conclusion.

Relevance to the current work: This article discussed interactions using robots as social agents with children with autism.

Mundy, P., & Crowson, M. (1997). Joint attention and early social communication: Implications for research on intervention with autism. *Journal of Autism and Developmental Disorders, 27*(6), 653-676.

Purpose of the work: The authors reviewed the current research on early intervention for children with autism and the efficacy for using measures of joint attention and early social communication during intervention.

Summary: Research has shown that early intervention for children with autism may lead to considerable gains in their development. Children with autism have serious difficulty with developing nonverbal joint attention skills. Typically, children with autism rarely point to or show objects for the purpose of socially inter acting and sharing their experience with others. These nonverbal joint attention skills may predict other aspects of development, especially language. Measures of a child's joint attention and ability to initiate social communication should be a priority within intervention. The skill of initiating joint attention bids may be an important target for early intervention. Research suggests that the ability of children to engage in joint attention with others contributes to the development of symbolic play skills, language, and social-cognitive processes. The neurological systems for children with autism were discussed. The authors stated that without adequate early social input and intervention, children with autism will experience delayed neurological and behavioral development. A cybernetic model of autism was discussed which shows the effects of an initial neurological disturbance which feeds back upon itself, giving rise to additional disturbances in neurological development of children with autism.

Conclusions: The authors argued for assessment and early intervention for children with autism to focus on non-verbal social communication skills, which will better enable researchers to understand the growth and development of children with autism.

Relevance to the current work: This article discusses the efficacy of targeting joint attention in intervention for children with autism.

Mundy, P., & Sigman, M. (2006). Joint attention, social competence, and developmental psychopathology. In Cicchetti, & Cohen (Eds.), *Developmental Psychology (Vol. 1: Theory and Methods*, (pp. 293-332). Hoboken: Wiley.

Purpose of the work: Mundy and Sigman discuss the development of joint attention and social competence. The connection between joint attention and social competence is explained through various models.

Summary: Joint attention is fundamental to the development of social competence. Typically, children develop different forms of joint attention between 3 and 18 months of age. Three forms of joint attention are: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). Children with autism typically display marked deficits in both IJA and RJA. Previous research and theory have led to the development of four models demonstrating the link between joint attention and social competence. These models are: the caregiver/scaffolding model, the social-cognitive model, the social motivation model, and the neurodevelopmental executive function model. The caregiver/scaffolding model emphasizes the importance of early parent-infant interactions of "joint engagement" which can form a rich interactive context in which children develop joint attention. During these joint engagement episodes, parents scaffold the interaction to the abilities of their child. The social cognition model demonstrates that before infants acquire language, they develop the ability to intentionally communicate information with their social partners through nonverbal actions such as pointing, showing, and eye contact. The social motivation model suggests that infants are motivated to engage in interactions with others due to a neural motivation system associated with positive rewards for interacting. The neurodevelopmental model suggests that joint attention impairment in children with autism may reflect a disturbance in the neural systems in the brain.

Conclusions: Current research is beginning to show that the study of joint attention skills in children may provide helpful information regarding the development of social competence. The authors recommend further research investigating each theory they discussed.

Relevance to the current work: This article discusses the connection between joint attention and social competence and the theories which address the development of joint attention.

Rapin, I. (1991). Autistic children: Diagnosis and clinical features. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1708491

Purpose of the work: The author describes the characteristics, clinical features, and diagnostic criteria for autism.

Summary: Because autism is a behavioral syndrome, the criteria for diagnosing autism are entirely behavioral. According to the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-III-R)* a person must manifest deficits in three areas of behavior including "(1) qualitative impairment in reciprocal social interaction, (2) qualitative impairment of verbal and nonverbal communication and imaginative activity and (3) a markedly restricted repertoire of activities and interests" (p. 752). Social deficits which are present in children with autism are: abnormal reciprocal-social interaction, abnormal gaze, lack of awareness of other's feelings and how to engage others in interaction. Characteristic of children with autism is the failure to acquire language at the typical age. Some children start to speak later in age and at first may produce unintelligible jargon, exhibiting very little communicative intent. Children with autism who are verbal experience difficulty with communication in terms of maintaining a topic, turn-taking, making eye contact, and interpreting the facial expressions, tone, and body language of their conversational partners.

Two diagnostic categories requiring differentiation for preschool children are between autism and mental deficiency (in low-functioning children) and autism and developmental language disorders (in high-functioning children). Once a diagnosis is made for a child, an individualized management program is created which accounts for the child's present level of functioning and their prognosis.

Conclusions: Autism in children is variable, with a broad range of severity of disabilities and levels of functioning. Autism makes itself manifest during the preschool years, and more frequently affects boys. There is no known cure for the disorder, although there are medications used to decrease the severity of some of the symptoms experienced. Intervention with children with autism seeks to improve their communication and social skills. The amount of improvement seen in each individual with autism is dependent upon the severity of the disorder.

Relevance to the current work: This article discusses the characteristics of autism and how it is clinically diagnosed.

Richey, S. (2011). ***Social engagement behaviors of two children with ASD in intervention sessions using a robot*** **(Unpublished master's thesis). Brigham Young University, Provo, Utah.**

Purpose of the study: Richey evaluated the behaviors of two children with ASD during intervention sessions with a robot. The treatment provided with the robot was low-dose, meaning the interactions with the robot were about 10 min in length (out of a 50 min long session). The study focused specifically on the initiation of social engagement behaviors in the two children during these sessions with the robot.

Method:
Participants: The participants were two children with ASD. Both children had previously attended the Brigham Young University Clinic for a year prior to participation in the study. During their previous interventions, neither child had made notable progress in social engagement behaviors or joint attention.

Procedures/Assessment Instrumentation: Each child participated in 16 intervention sessions lasting 50 minutes. Forty minutes of the session involved traditional therapy, while 10-15 minutes of the session included a triadic interaction which took place with the robot. Each of these triadic interactions were broken up into 5 second intervals and coded for social engagement behaviors. Four specific initiating engagement behaviors were identified and coded: language, affect, imitation, and eye contact.

Results: Both participants demonstrated gains in initiating social engagement behaviors with the robot and with adults, especially in the initiation of engagement with adults through the use of eye contact.

Conclusions: The use of the robot provided motivation for each participant to interact. The low-dose, highly interactive design of the study seemed to produce an increase in the participant's initiations of social engagement. Results suggest that subsequent research continue to investigate the potential use of humanoid robots to facilitate social engagement behaviors in children with autism.

Relevance to the current work: The current study is a more comprehensive investigation of this treatment approach.

Ricks, D. (2010). *Design and evaluation of a humaniod robot for autism therapy* (Unpublished master's thesis). Brigham Young University, Provo, Utah.

Purpose of the study: Ricks developed a humanoid robot for use in therapy for children with autism. The robot was designed for use as an intervention tool.

Method:
Participants: Clinical trials were completed with two typically developing children, one child who had developmental and behavioral handicaps without autism, and one child with autism. The participant with autism was an 8 year old male who demonstrated deficits in social engagement behaviors and joint attention.

Procedures/Assessment Instrumentation: Each participant took part in a triadic interaction with a graduate clinician, and assisting graduate clinician, and the robot. The robot was placed in the middle of the room, on the floor or a table. Troy, the robot was programmed with various facial expressions and actions intended to help engage the child. For the trial with the child with autism, a familiarization stage was used to help the child become accustomed to Troy. The child was introduced to Troy, but then resumed traditional therapy for 40 minutes. Troy was then incorporated into the interaction for the last 10 minutes of the therapy session.

Results: The two typical participants engaged with the clinicians and robot during the interaction. The developmentally handicapped child showed positive affect while engaging with the robot and the clinicians. The child with autism initially showed mild interest in the robot during the familiarization stage. While interacting with Troy and the clinicians, the child with autism showed positive affect and was highly motivated to participate.

Conclusions: Preliminary clinical results show that the robot Troy is an engaging tool for therapy with children. Further research should be conducted to determine the long-term benefits of using robots for autism therapy.

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

Scassellati, B. (n.d.). How social robots will help us to diagnose, treat, and understand autism. Retrieved from http://robots.stanford.edu/isrr-papers/draft/scassellati-final.pdf

Purpose of the study: Scassellati reported information on social robots based on three years of work with a clinical research group. The study discussed how social robots will impact our clinical understanding, diagnosis, and treatment of autism.

Research has shown that robots generate a high degree of motivation and engagement when used in therapy for children with autism. However, it remains unclear exactly what aspects of the robot are so engaging to this population. The ultimate goal is to use the robot to teach social engagement skills and help children in the transfer of these skills to human interactions.

Method:
Procedures/Assessment Instrumentation: The research team created a robot named ESRA. ESRA was programmed to display various facial expressions in an attempt to engage the child and elicit a range of social skills and behaviors.

One method used to obtain data for diagnosis was through passive sensing, involving motion sensors used to detect the following: eye gaze, the position of individuals as they move throughout a room, and vocal prosody. A second method for obtaining data was through interactive social cue measurement, with the use of an interactive robot.

Results: Typical children were often engaged with the robot initially, but lost interest in interacting with the robot. Children with autism often attended to the robot, even when it was not initiating or responding to the child.

Conclusions: The use of a social robot helped to facilitate the collection of quantitative and objective data for diagnosis. Additional research should be completed to develop a more interactive robot effective in intervention for children with autism.

Relevance to the current work: This article addressed methods to collect data from interactions between children with autism and robots.

Seibert, J. M., Hogan, A. E., & Mundy, P. C. (1982). Assessing interactional competencies: The early social communication scales. *Infant Mental Health Journal 3*(4), 244-245.

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 later social development. An overview of the Early Social-Communication Scales (ESCS) and its behavioral content was presented.

Summary: Within the application of the ESCS, three primary functions representing emerging social skills were identified: social interaction, joint attention, and behavior regulation. Social interaction refers to the behaviors primarily used in play to gain the attention of another person. Joint attention is the ability to maintain shared focus with another person on the same object or event.

The ESCS is comprised of five organizational levels. *Level 0: Reflexive or Responsive* takes place in the first two months of a child's life. The child is characterized are reflexive or responsive because they have not acquired more differentiated and advanced levels of interactive skills. *Level 1: Simple, Voluntary Interactions* occurs between 2 to 7 months. The infant is gaining voluntary control over their behavior patterns. The child initiates interaction through gesture or 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 social interactions, the child's actions become more deliberately modified to the situation and their communicative partner. *Level 4: Anticipatory Regulation of Interactions* occurs between 18 and 22 months. This level is characterized by symbolic or representational thought where the child can anticipate the consequences of their actions. Their language abilities also progress from a conventional signal level to a symbolic level. The ESCS can be administered as a caregiver questionnaire or a formal assessment.

Conclusions: The ESCS goes beyond the traditional developmental checklist and developmental scales. Normative longitudinal data from a sample of children should be gathered to provide further validation of the effectiveness of the ESCS.

Relevance to the current work: This article discusses emerging social skills and the early social communication scales.

Westby, C. E. (2010). Social-emotional bases of communication development. In B. B. Shulman, & N. C. Capone (Eds.), *Language development: Foundations, processes, and clinical applications* (pp. 135-176). Boston: Jones and Barlett.

Purpose of the work: Westby presented the characteristics of language and communicative competence. The author also discussed factors that influence the development of social and communicative competence (i.e. child characteristics, disabilities, and environmental factors).

Summary: Theory of Mind (ToM) is the ability of a child to make appropriate inferences which are essential for social interactions. Within ToM, the child recognizes that their peers have experiences and opinions which may differ from their own. Joint attention "involves 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). Westby discusses three types of joint attention (JA). Responding to joint attention (RJA) occurs when the child follows the direction of eye gaze, gesture, or head turns of another person. Initiating joint attention (IJA) involves the child using eye contact or gestures to spontaneously initiate interaction with a communicative partner. Initiating behavior requests (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, children with autism typically will eventually develop RJA and IBR, but continues to show deficits in IJA.

Westby discussed the development of language skills in typically developing children. The social-emotional development in children, especially reflected through joint attention, initially enables the development of language. In later years, language is the tool through which children develop further social-emotional cognition. Children with autism spectrum disorders (ASD) experience difficultly establishing joint attention and affective contact with others. With this inability to enter social interactions, the child with ASD will have difficulty developing JA, ToM, and further social-emotional cognition.

Westby also discussed ways to measure and assess the communicative behaviors children exhibit. These assessments can involve formal measures, informal measures, and parent interviews. Westby identified several approaches and aspects of treatment that are important to include in social engagement interventions for children with ASD.

Conclusions: The development of social engagement behaviors (i.e. IJA, RJA, and IBR) is essential for social communication. True communication and language depend on the social-emotional competence and the motivation of children to engage socially with others. The deficits which children with ASD exhibit in IJA greatly impact the child's social development. It is important to target 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 and provided definitions of the three types of joint attention: IJA, RJA, and IBR.

Appendix C

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"**

Noisy Ball
Roll the ball to client ☐ ☐ ☐

Say **"ROLL IT TO ME"** or **"MY TURN"**

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 child ☐ ☐ ☐

Give to clinician then child ☐ ☐ ☐

Push to clinician then child ☐ ☐ ☐

Give to clinician then child ☐ ☐ ☐

Appendix D

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.

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 ☐ ☐

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

Eye Contact: ☐ ☐ ☐

Reciprocal Action: Returning ball to clinician ☐ ☐ ☐

Language: Signs or speaks about ball or about activity topic ☐ ☐ ☐

Initiating: At conclusion of probe, child says or signs "again" or "more" ☐ ☐ ☐

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

Eye Contact: ☐ ☐ ☐

Reciprocal Action: Returning car to clinician ☐ ☐ ☐

Language: Signs or speaks about car or about activity topic ☐ ☐ ☐

Initiating: At conclusion of probe, child says or signs "again" or "more" ☐ ☐ ☐

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 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

Initiating prototypes:

Eye Contact: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Initiating: Give to clinician independently ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Language: signs or speaks about wind-up toys or activity topic
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

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

Eye Contact: ☐ ☐ ☐

Symbolic play:
Cuddle, hug, kiss, or rock baby with or without blanket
Put on blanket/wrap up baby
Cover 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

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 ☐ ☐

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

Eye Contact: ☐ ☐ ☐

Reciprocal Action: Returning ball to clinician ☐ ☐ ☐

Language: Signs or speaks about ball or about activity topic ☐ ☐ ☐

Initiating: At conclusion of probe, child says or signs "again" or "more" ☐ ☐ ☐

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

Eye Contact: ☐ ☐ ☐

Reciprocal Action: Returning car to clinician ☐ ☐ ☐

Language: Signs or speaks about car or about activity topic ☐ ☐ ☐

Initiating: At conclusion of probe, child says or signs "again" or "more" ☐ ☐ ☐

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 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

Initiating prototypes:

Eye Contact: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Initiating: Give to clinician independently ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Language: signs or speaks about wind-up toys or activity topic
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

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)
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

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"
☐☐☐ ☐☐☐ ☐☐☐ ☐☐☐