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Effect of a Humanoid Robot During Therapy on Responding to Joint Attention with Children with Autism Spectrum Disorder

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ABSTRACT

Effect of a Humanoid Robot During Therapy on Responding to Joint
Attention with Children with Autism Spectrum Disorder

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This study examined the use of a humanoid robot to engage two children with Autism Spectrum Disorder (ASD) on responding language behaviors including language, affect, imitation, and eye contact. The robot was integrated into each child's regular intervention in low-doses (10 min of a 50 min session). The goal was to increase responding language behaviors in the children with their conversational partners. The two children participated in pre and post assessment sessions as well as 16 intervention sessions. The data from these sessions were coded into two main categories including how the children interacted (*Initiating Engagement*, *Responding to Engagement*, and *Non-Engagement)* and who the children interacted with *(Robot Only* and *Both).* Both children improved in response to the intervention indicating a relation between improved behavior and intervention with the robot.

Keywords: ASD, robotics, responding, language, joint attention

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Introduction

Autism Spectrum Disorders (ASD) include a group of disorders such as Pervasive Developmental Disorder Not Otherwise Specified, Autistic Disorder, Rett's Disorder, and Asperger's syndrome (Prelock, 2006). It is a behavioral disorder that begins in childhood with behavioral characteristics manifesting themselves before the age of three (Campolo et al., 2008). These characteristics involve three areas of development: social interaction, language and communication, and patterns of interests such as restricted, repetitive, stereotyped behaviors (Belmonte et al., 2004; Campolo et al., 2008; Keller & Persico, 2003; Volker & Lopata, 2008). These behaviors impact communication with other people in social settings. In individuals with severe impairments, productive language may be severely delayed or may fail to develop entirely. A primary problem for many low functioning individuals with ASD is the lack of joint attention behaviors (Belmonte et al., 2004).

Joint Attention

Joint attention refers to a group of nonverbal behaviors that infants develop as they communicate with others about entities separate from themselves. Mundy, Sigman, Ungerer, and Sherman (1986) explain that the purpose of joint attention is to share awareness of the object or event of interest to accomplish a communicative goal. To do this, behaviors such as showing are used to coordinate the attention of two communicating partners. In addition to showing, behaviors used to share awareness with others include alternating eye gaze and gesturing (Bruinsma, Koegel, & Koegel, 2004). To accomplish joint intention, an individual must be able to alternate and divide attention between an object and communication partner (Bakeman & Adamson, 1984).

There are three general categories of joint attention behaviors. The first one is response to joint attention, which includes responding to another's nonverbal behavior such as pointing or shifts in eye gaze. The second is initiation of joint attention, or when a child seeks another's attention (Bruinsma et al., 2004). The third type of joint attention is initiating behavior regulation/requests, in which the child uses initiation of joint attention behaviors such as eye contact or gestures to obtain objects or actions (Seibert, Hogan, & Mundy, 1982).

The ability to respond to joint attention, initiate joint attention, and initiate and respond to behavioral requests generally increases as infants grow older, but there is heterogeneity among individuals. These variations correspond to the child's successive abilities in language, cognition, and social development (Mundy et al., 2007). Seibert et al. (1982) describes five levels within the development of joint attention. The first level begins before two months of age and is *Reflexive* or *Responsive* in which the infant does not respond to interaction intentionally but responds by being soothed or attending to an object. The second level occurs between two and seven months and is *Simple, Voluntary Interactions.* At this level the infant begins to develop more controlled behaviors such as looking at objects or individuals, reaching, vocalizing, and gesturing. In the third level, infants around eight to 12 months develop *Complex Differentiated Interactions*. At this level, the infant develops intentionality to communicate by displaying behaviors such as responding to his/her name, initiating requests for attention, and alternating gaze between an object and individual. In the fourth level the infant develops *Immediate Modification of Interactions to Feedback* around 13 to 21 months. At this time, the infant is able to focus on both an individual and an object and begins to show behaviors such as spontaneously initiating joint attention, turn-taking, and looking at objects that individuals point to. The child also begins looking at, naming, and using one-word utterances to direct attention.

In the last level, infants begin *Anticipatory Regulation of Interactions* at about 18 to 22 months. At this stage, infants begin to use symbols to represent thoughts and display behaviors such as pretend play and responding to joint attention directed at an object out of their view.

Joint attention develops in concert with the intention to communicate and is fundamental to the development of language (Bakeman & Adamson, 1984; Bruinsma et al., 2004; Calandrella & Wilcox, 2000; McCathren, Yoder, & Warren, 1999). Joint attention impacts early language learning in two ways. First, as a child and an adult participate in joint attention activity with each other, they create a non-linguistic scaffolding context to learn early language. Second, when engaged in joint attention with an adult, the child is attentive and motivated to learn. As a result of this attention, the child is better able to learn the structure in the context(s) that the adult used it (Tomasello & Farrar, 1986). Therefore, failure to develop joint attention results in deficits in language acquisition (Mundy, Sigman, & Kasari, 1990). Children with ASD use fewer joint attention behaviors such as eye contact, giving, showing, pointing at objects, following points, and use of preverbal noises communicatively (Bruinsma, Koegel, & Koegel, 2004; Wimpory, Hobson, Williams, & Nash, 2000). As a result of these deficits, these children have fewer ideal opportunities to learn language. As is suggested by these outcomes, a lack of joint attention in early development is cause for serious concern.

Intervention can effectively increase joint intention in children with ASD. For example, Jones (2009) studied two boys with ASD and found deficits in joint attention during baseline measures. After receiving joint attention intervention, both children improved in alternating eye gaze to initiate joint attention, combining gaze alternating and pointing, and combining gaze alternating, pointing, and verbalizing. To illustrate these gains, the first child’s improvements are discussed. Luke showed joint attention behaviors such as alternating eye gaze between 1 and

3 times (25-60%) compared to typical criterion (80% independent eye gaze alternation). Luke also demonstrated pointing paired with alternating eye gaze on only one occasion. After 15 sessions of intervention, Luke gained mastery, or 80% independent initiation of joint attention across two sessions. Luke acquired the ability to initiate joint attention by combining alternating eye gaze and pointing after another 19 sessions with the same criterion and 22 sessions following that, Luke was able to initiate joint attention by combining alternating eye gaze, pointing, and a one word verbalization.

Kasari, Gulsrud, Wong, Kwon, and Locke (2010) also attempted to determine if treatment would increase joint attention between the child and parent. These researchers studied 38 parents and their children with ASD between the ages of 21 to 36 months. The children were separated into two groups. One group started intervention immediately and the second began therapy 8 weeks later, each group participating in treatment for 8 weeks. Intervention consisted of a professional coaching the parent and child interaction in play routines using responsive and facilitative interaction methods and applied behavior analysis techniques. Video-recordings of the child/parent interaction were analyzed for the percentage of time in which the child and parent were engaged and the occurrence of functional and symbolic play acts and joint attention behaviors before therapy began, after therapy ended, and 12 months after intervention ended. Kasari et al. (2010) found that as the intervention progressed, the children’s skills improved in the areas of engaging in interaction, responding to bids for joint attention, and playing skills with their parents. Work, such as the studies cited above, indicate that joint attention can be facilitated through direct intervention.

Technology and Intervention for Children with Autism Spectrum Disorder

In general, technology has been successfully utilized in speech and language intervention for children with autism. For example, computers have been used to teach a variety of behaviors to these children, including increasing motivation, decreasing inappropriate behavior, and increasing attention (Bernhard-Opitz, Sriram, & Sapuan, 1999; Bosseler & Massaro, 2003; Goldsmith & LeBlanc, 2004; Heimann, Nelson, Tjus, & Gillberg, 1995; Moore & Calvert, 2000; Silver & Oakes, 2001; Taylor, Levin, & Jasper, 1999). Goldsmith and LeBlanc (2004) explain that technology can be used in intervention as an assistive tool to aid in intervention and be removed after a goal has been met. These authors indicated that children with ASD often need aid in the form of external stimuli to accomplish behaviors. These external stimuli have been effective for a wide range of goals. The use of robots in intervention with autism is a seemingly unlikely use of technology that has produced intriguing outcomes. Of particular interest for present purposes is the use of a robot as a mediator to encourage interaction with other individuals.

Robotics and ASD

A number of researchers have employed robots in intervention with children with ASD (Duguette, Michaud, & Mercier, 2008; Pierno, Marl, Lusher, & Castello, 2008; Wainer, Ferrari, Dautenhahn, & Robins, 2010). Several positive results have been found. For example, placing robots into intervention sessions with children with ASD has resulted in more engaged interaction on the part of the children receiving services (Giannopulu & Pradel, 2010). Children with ASD also exhibit more social acts towards the robot and other humans when a robot is included in behavioral intervention sessions (Feil-Seifer & Mataric, 2009).

Robots used in intervention with children with ASD also can be used as a motivator for communication. The robot can act as a social mediator, joint attention referent through use of eye contact, and attention referent in order to communicate between the child and another adult (Robins, Dickerson, Stribling, & Dautenhahn, 2004). Robots have also been used to aid a child with ASD to expand interactions from a dyadic interaction with the robot to a triadic interaction with a human to express emotion (Kozima, Nakagawa, & Yasuda, 2005)

Many studies have used robots in intervention to improve particular behaviors. By way of illustration, Pierno et al. (2008) examined the affect of robotics on imitative behaviors in children with ASD. These researchers compared a group of children with high functioning autism to a group of typically developing children. Each participant was required to observe either a human or a robotic arm model performing a task. Participants were then asked to complete the same task. Children with ASD were able to accomplish the task more effectively after observing a robot as compared to a human arm. The opposite was found for the typical children.

Duguette et al. (2008) examined the use of robotics on children with ASD to teach imitation. Four children with ASD were used: two were paired with a robot mediator and two were paired with a human mediator. Each mediator conducted sessions to elicit imitation. Children with ASD who were paired with humans produced more imitative acts than children paired with robots. On the other hand, the children paired with the robot showed other interesting improvements. These children demonstrated increased shared attention, including eye contact and physical proximity, and imitation in facial expressions compared to the children that were paired with humans.

Wainer et al. (2010) examined the affects on collaboration skills on children with ASD in a robotic programming class. The collaboration skills that were analyzed were the extent to which the children (a) stood within 120 cm of each other, (b) shared gaze, (c) talked about the robot with another individual, (d) pointed, and (e) shared affect. Children with ASD programmed Lego robots in a class that took place once a week for several months. The amount of collaborative behaviors correlated with amount of enjoyment the children were experiencing.

Current Study

The present study is one aspect of a larger project assessing an intervention to facilitate joint attention in children with ASD employing a humanoid robot in the intervention. Two graduate student clinicians performed speech-language intervention with two children with ASD, Clark and Abe. Traditional intervention methods were supplemented with a robot to target joint attention behaviors. Traditional intervention was provided for 40 min of the session. During 10 min of each session the robot was used. These 10 min segments were randomly placed during the sessions. Each child participated in 16 sessions. Baseline and follow-up sessions were taken for each child. Changes in behavior were examined by comparing frequency of the target behaviors from the baseline to follow-up sessions that included four contexts: child-parent play, child-clinician play, triadic interaction, and unfamiliar adult interaction. Data were gathered using the same data analysis system as the current study. This analysis system involved looking at joint attention behaviors in *Initiating Engagement* and *Responding to Engagement.* Behaviors studied in each category were language, affect, imitation, and eye contact (Acerson, 2011; Hansen, 2011).

Acerson (2011) analyzed the pre and post assessments during samples of the child-parent and child-clinician play. Abe demonstrated an increase in 87.5% of the targeted behaviors during both post treatment sessions as compared to pre treatment sessions. Clark's performance was more variable. He demonstrated an increase or maintenance in all targeted behaviors in either responding to or initiating engagement when child-clinician pre and post treatment assessments were compared. He did, however, display a decrease or no increase in 75% of the targeted behaviors in the child-parent condition. Beyond these targeted behaviors, both Clark and Abe improved by generalizing the ability to greet other individuals outside of intervention sessions and decreased their restricted interests and repetitive play behaviors (Acerson, 2011).

Hansen (2011) analyzed the pre and post assessments during triadic interaction with the two graduate clinicians and interactions with an unfamiliar adult. Results indicated that Abe demonstrated an increase in 81.3% of targeted behaviors in both the triadic and unfamiliar adult interaction contexts. Clark demonstrated an increase or maintenance in 81.3% of all targeted behaviors in both the triadic and unfamiliar adult interaction contexts. It was also observed that both children combined behaviors more often including eye contact with language or affect in the post assessments. On the other hand, Abe's non-engagement behaviors also increased from all pre to post assessments in triadic and unfamiliar adult interactions. Clark's non-engagement behaviors increased from pre to post assessments in the triadic interactions.

The present study examined joint attention behaviors of these same two children across the 16 intervention sessions. Behaviors that were analyzed included responding to bids for interaction including imitation, verbalization, affect, and eye contact. The independent variables include the robot and the therapy sessions and the dependent variable is the frequency and duration of joint attention behaviors. This study addressed the following questions:

1. Does low-dose involvement of a humanoid robot in joint attention intervention aid in increasing imitation behaviors?

2. Does low-dose involvement of a humanoid robot in joint attention intervention aid in increasing verbalization?

3. Does low-dose involvement of a humanoid robot in joint attention intervention aid in increasing affect?

4. Does low-dose involvement of a humanoid robot in joint attention intervention aid in increasing eye contact?

Method

Participants

Two male children diagnosed with ASD who exhibited moderate to severe deficits in social and communicative function participated in this study. The two participants demonstrated limited joint attention behaviors and moderate to severe language delay. These two children received services at the BYU Speech and Language Clinic and showed little improvement in social communication after a year of speech and language intervention (Acerson, 2011; Hansen, 2011). The participants are referred to as Abe and Clark to insure confidentiality.

Abe. Abe was 3:7 (years: months) at the beginning of this study. The following information was obtained from Abe's file at the BYU Speech and Language Clinic including information from intake forms filled out in March 2009 and subsequent interviews with his mother. He was diagnosed with PDD-NOS, hypotonia, language delay, sensory problems, and gross motor delays in September 2009 (age 2:6) by a neurologist and psychologist. The psychologist used the Autism Diagnostic Observation Schedule (Lord, Rutter, DiLavore, & Risi, 1999) to diagnose Abe with PDD-NOS.

Abe received speech, language, and physical intervention beginning at the age of 10 months, once a month, through an early intervention program. This therapy included a parent education treatment plan. Abe also received speech and language services at his preschool starting in September 2009. His Individualized Education Plan (IEP) goals consisted of discriminating colors, discriminating shapes, demonstrating understanding of the concepts of *same* and *different*, improving his ability to initiate and maintain social interactions with his peers, demonstrating willingness to participate in structured classroom activities, improving receptive and expressive language skills through the use of words and signs, and improving fine motor skills.

Abe was initially seen at the BYU Speech and Language clinic in March 2009 (age 30 months). Abe's intervention at BYU targeted (a) improving his play skills and his ability to participate in symbolic play; (b) improving his joint attention skills such as eye contact, initiating activities, and taking turns; (c) improving his receptive language skills; and (d) improving his expressive language skills through verbal language and gestures. Follow-up data were taken in November 2009 assessing his progress. Data revealed that Abe demonstrated an understanding of commands to hold hand, sit down, and clean up with visual support. Abe's clinician also reported that expressive language skills consisted of the ability to imitate verbalizations of /l/ and /f/, produce a vowel-like vocalization, imitate the h sound, use the vocalization /mamama/ appropriately with moderate support, point with moderate support, and attend to an interactive toy for 7 min with moderate support. Abe's joint attention skills at the time of the follow-up consisted of the ability to take one turn with no support during a motivating activity. Abe's play skills consisted of the ability to feed a doll with maximal hand-over-hand support. Abe's clinician reported that he enjoyed playing with dolls but lacked the ability to pretend play.

Clark. Clark was 7:11 years at the beginning of this study. The following information was taken from Clark's file at the BYU Speech and Language Clinic. Clark was diagnosed with attention deficit hyperactive disorder (ADHD) at age 3 and medication was prescribed as a treatment. When Clark was four-years-old, a child psychologist diagnosed him with ASD. Prior to integrating the robot into Cark's therapy sessions, Clark did not speak in sentences and communicated with 2-4 word phrases. He responded to smiles from others with a smile, and struggled to make eye contact with most individuals. At home, Clark only communicated basic needs.

Clark received intervention services at the BYU Speech and Language Clinic, beginning in September of 2008, for two semesters prior to participation in this study. Intervention targeted speech, language, and social function delays secondary to ASD. His goals included (a) improving his level of engagement during activities with a conversational partner through increasing frequency of eye contact; (b) improving his ability to participate in constructive play through participating in reciprocal play; and (c) increasing his expressive language through using phrases to communicate wants and needs and making appropriate comments in structured activities.

Follow-up data were taken after a semester of intervention in June 2009 to assess Clark's improvement over the course of the semester. The clinician found that Clark's joint attention skills consisted of the ability to make appropriate eye contact with his clinician eight times during a 50-min session. Clark's play skills consisted of seven instances of imitating his clinician's model, and one instance of initiating reciprocal play. The follow-up data revealed that Clark's expressive language skills consisted of using nine three-word phrases to communicate preferences, and making 21 appropriate comments during three structured activities within a 50-min session. During intervention sessions, Clark required external support such as manual regulation from the clinician to maintain attention to activities and stay in the clinic room.

Robot

Troy was a humanoid robot created by graduate students from the Brigham Young University Department of Mechanical Engineering. He was designed for and used in intervention with the two participants described above. The primary focus of the intervention was to target joint attention skills. Troy was capable of interacting through actions such as pushing a car, tapping a tambourine, waving hello, looking at an individual, etc. in order to engage the children and encourage requesting and initiating activities.

Troy was capable of executing specific human actions of the upper body including moving the arms and neck, making basic facial expressions, and producing verbal songs and phrases. Troy's arms could move in four different directions, including shoulder flexion/extension, shoulder abduction/adduction, humeral rotation, and elbow extension/flexion. Wrists and hands were not included in the design because it was determined that the benefit of having hands did not merit the size and cost of the material and motor needed. Troy's neck was able to move anteriorly, posteriorly, and laterally. Both Troy's arm and neck movements were powered through RC servo motors. Troy also contained a LCD monitor encased in a plastic frame for his head that displayed different human emotions including a sad face, neutral face, and happy face. Troy also had the capability of making noise, which was accomplished through a connection to a laptop. Sounds, phrases, and songs were pre-recorded and stored in the computer and could be played through the laptop speakers or through external speakers that were connected to a computer. Troy was 25 in. (63.5 cm) tall including his core body, neck, and head.

His arms were 12 in. (30.48 cm) long. He stood on a base with dimensions of 9 x 11 in. (22.86 x 27.94 cm) (Ricks, 2010).

The clinician was able to control Troy's movements using a Wii remote. It was connected to the computer through Bluetooth technology. Each action was controlled through buttons on the Wii remote to make Troy appear to be acting on his own volition. Troy was plugged in an outlet to receive power. A graphical user interface (GUI) was installed on a laptop that was located in the therapy room. This interface was used to program Troy's actions, which were choreographed through preprogrammed movements through the interface. Sequences of actions could be programmed by dragging and dropping onto a screen (Ricks, 2010).

Figure 1. Troy from the front, side, and back. Pictures were adapted from "Design and Evaluation of a Humanoid Robot for Autism Therapy" by Daniel Ricks, 2010, Brigham Young University, Provo. Reprinted with permission.

Treatment Procedure

The treatment was administered from January 2010 to May 2010. Intervention was provided twice a week (50 min per session). The therapy sessions were based on an intervention model that was family centered, naturalistic, interactive, and child-centered. Abe's mother and infant sister were in the intervention room for most sessions. Clark's siblings were occasionally in the sessions. There were 20 sessions total, which included two pre-treatment sessions, 16 intervention sessions, and two post-treatment sessions. Some sessions were canceled due to illness or holidays, but these sessions were made-up. All treatment sessions were audio and video recorded with two cameras. One was mounted on the wall while the other one was operated by an undergraduate student in the room. The handheld camera was used to focus tightly on the child's face to allow more reliable coding of joint attention behavior (Acerson, 2011; Hansen, 2011).

Pre-Treatment Sessions. The sessions prior to the beginning of treatment were used to collect baseline data on the two children's joint attention behaviors. Play scenarios were set up for the assessment process including a child-parent play assessment, a child-clinician play assessment, a triadic interaction assessment, and an unfamiliar adult assessment. During the child-parent play assessment, play behaviors were observed and data were taken on the amount of joint attention behaviors in which the child participated. During this assessment, the child and his parent were left alone in the room, along with the undergraduate student operating the handheld camera. This interaction lasted for 20 min and the parent was instructed to play with the child as naturally as possible. The following toys were available to play with: two trucks, a bus, a fire truck, two helicopters, play food, dishes, dolls, a puzzle, and blocks (Acerson, 2011; Hansen, 2011).

During the child-clinician play assessment, the clinician and the child were left alone in the room, along with the undergraduate student operating the camera, to play with the following toys: three dolls, doll accessories, baby bottles, a tea set, a dump truck, a car garage, two toy cars, wood blocks, a telephone, a hair brush, and a mirror. The clinician attempted to interact with the child by handing him a toy and waiting to see if the child would play with the toy appropriately. If the child played with the toy appropriately, the clinician then commented on the interaction and attempted to join in the play to elicit joint attention. If the child did not play with the toy appropriately, the clinician would model appropriate behavior and gave the child another opportunity to play with the toy (Acerson, 2011). These play behaviors were measured through data collected on joint attention behaviors produced by the child during interaction with the graduate clinician.

During the triadic interaction assessment the child was placed in a room with the child's primary clinician and another graduate clinician. The clinicians used toys such as a push car, tambourine, music-making hand operated toy, and a ball to try and engage the child in a triadic interaction. To do this, the child's clinician would perform an action with a toy, followed by the second clinician doing the same action. The first clinician would then invite the child to join the interaction. If the child joined, the clinicians would continue the interaction. If the child did not join, the clinicians would repeat the routine 2 to 3 more times. Each toy was used in the assessment (Hansen, 2011).

In the unfamiliar adult assessment an unfamiliar adult attempted to engage the child in play using a wind-up and hand-operated mechanical toys, a hat, a comb, glasses, a ball, a car, a balloon, and a book as well as songs. The adult would try to interact with the child using the toys and then waited for a response. If the child responded, the adult would continue to interact. If the child did not respond, the adult would attempt to interact 3 times and then would try to use another toy or song (Hansen, 2011).

Intervention Sessions. During each of the 16 intervention sessions, each child participated in 50 min of therapy, separated into 40 min of traditional intervention and 10 min of intervention with the robot randomly inserted into the session. During the 40 min segment, the clinician employed a naturalistic, interactive, and child-centered therapy approach. During the 10 min segment with the robot, the child, the graduate clinician, an assisting graduate clinician, and a family member were involved in the interactions. The child's graduate clinician was present to control the robot's actions and to provide therapy and elicit target behaviors in the child. The assistant graduate clinician was present to provide hand-over-hand modeling for the child as well as prompting the child to take part in interactions or to be another partner in engagement. During this time, therapy was designed to elicit joint attention behaviors in a triadic or quadratic interaction with the robot. This triadic or quadratic interaction usually involved the child, the graduate clinician, the parent, and the robot (Acerson, 2011; Hansen, 2011). The following exchange was used among the clinician, robot, and child to encourage the child to interact with the individuals in the room and the robot:

1. Clinician performs a gesture (e.g., puts hands up) and reacts with positive emotion.

2. Robot performs same action.

3. Robot reacts positively with sound or motion.

4. Clinician reacts to the robot's action with positive emotion (e.g., says Wow!)

5. Clinician prompts the child to perform the action (e.g., says, Now you do it.).

6. Assistant helps child via hand-over-hand to perform the same action.

7. Robot reacts positively to the child with sound or motion. (Hansen, 2011, p. 83)

Interactions were based on reciprocal turn-taking sequences. Several activities were used in conjunction with the reciprocal turn-taking sequences to promote joint attention including pushing a car, playing with a hand-operated music-making toy, playing with a tambourine, passing a ball, playing with a felt fishing set, bowling with a soft bowling set, and playing with pretend plastic food. These interactions were initiated by Troy, the clinician, or the child and would rotate among all three individuals. Troy would participate in each of these activities by doing such actions as pushing the car or ball or taking a turn playing the tambourine or fishing for felt fish. Troy also sang songs with actions such as *Popcorn Popping on the Apricot Tree* and *3 Little Monkeys Swinging in a Tree* (Acerson, 2011; Hansen, 2011). The child was required to interact with one of the graduate clinicians or family member before the robot participated in the interactional sequence. Data used in this study was gathered from these 16 robot intervention sessions.

Post-Treatment Sessions. After the 16 intervention sessions took place, follow-up data were gathered. The post-treatment sessions were executed in the same manner as the pre-treatment session. The two play assessments with the parents and graduate clinicians were used along with the same play materials. Data again were gathered on the amount of joint attention behaviors that each child participated in (Acerson, 2011; Hansen, 2011).

Data Analysis

Data were gathered and analyzed using an analysis system that was based on that employed by Kasari et al. (2006). Two graduate students, prior to this current study, analyzed the data gathered from the pre- and post-treatment sessions. The current study analyzed the 10-15 min robot sessions, which were randomly interspersed during 50 min long intervention sessions. Behaviors were analyzed and counted as the session videos were watched in 5-sec intervals. To observe and analyze these behaviors, two cameras video recorded each session and both recordings were set side by side using Final Cut Express software to provide multiple views of the child. The children's behaviors were coded into two main categories including how the children interacted and with who the children interacted. In the current study, the behaviors identified under *Responding to Engagement* were specifically observed and analyzed.

Interactions. The children's interactions with the adults were coded into three areas including *Initiating Engagement, Responding to Engagement,* and *Non-Engagement.*

1. *Initiating Engagement. Initiating Engagement* was coded when the child spontaneously initiated engagement with another individual.

2. *Responding to Engagement. Responding to Engagement* was coded when another individual attempted to engage with the child and they responded to the engagement. Attempts to engage with the child included closed statements, questions, and facilitated behaviors such as when the clinician attempted to make eye contact.

3. *Non-Engagement.* Behaviors categorized as representing *Non-Engagement* were identified as either *away from interaction* or *tantruming* such as screaming, kicking, physical aggression, or self-injurious behaviors.

In both the *Initiating Engagement* and *Responding to Engagement* categories there were several behaviors coded including *language, affect, imitation*, and *eye contact*. Guidelines were established for each category. *Language* was coded when the child was identified as verbalizing real words or close approximation of words. *Affect* was coded when the child was identified as laughing, jumping, clapping, and/or playful screaming. *Imitation* was coded when the child was identified as imitating or repeating an action observed by the communication partner. *Eye contact* was coded when the child was identified as looking at the upper half of the communication partner's face at the same time as the communication partner looking at the child. If two different behaviors were seen within the same 5-sec interval, both were marked as present.

Interactants. The interactants, or who the children interacted with, were also observed and coded into two areas including *Robot Only* and *Both.*

1. *Robot Only.* If the child attempted to engage with the robot and no other individuals within the 5-sec interval, those behaviors were coded under the *Robot Only* category.

2. *Both*. If the child attempted to engage with the robot and another individual, the *Both* category was marked as well as in the appropriate behaviors in the *Initiating Engagement* or *Responding to Engagement* sections.

Reliability

Two graduate students coded all the robot sessions, each student individually coded approximately half of the 32 sessions. To establish reliability, the two examiners were taught the coding system prior to coding. After all the sessions were coded separately, 12.5% of the videos were recoded by the other examiner and coding agreement of 93-97% was established across the individual categories including *language, affect, imitation,* and *eye contact* in *Initiating Engagement* and *Responding to Engagement* categories as well as *Non-Engagement, Robot Only*, and *Both*.

Results

Abe's Performance

Social Engagement with Caregiver and/or the Clinician. Figure 2 represents the total number of instances during baseline, intervention, and follow-up in which Abe responded to engagement with an adult. There is some variation, however, a general increase in the number of interactions with adults over the course of the intervention was noted. Decreases often

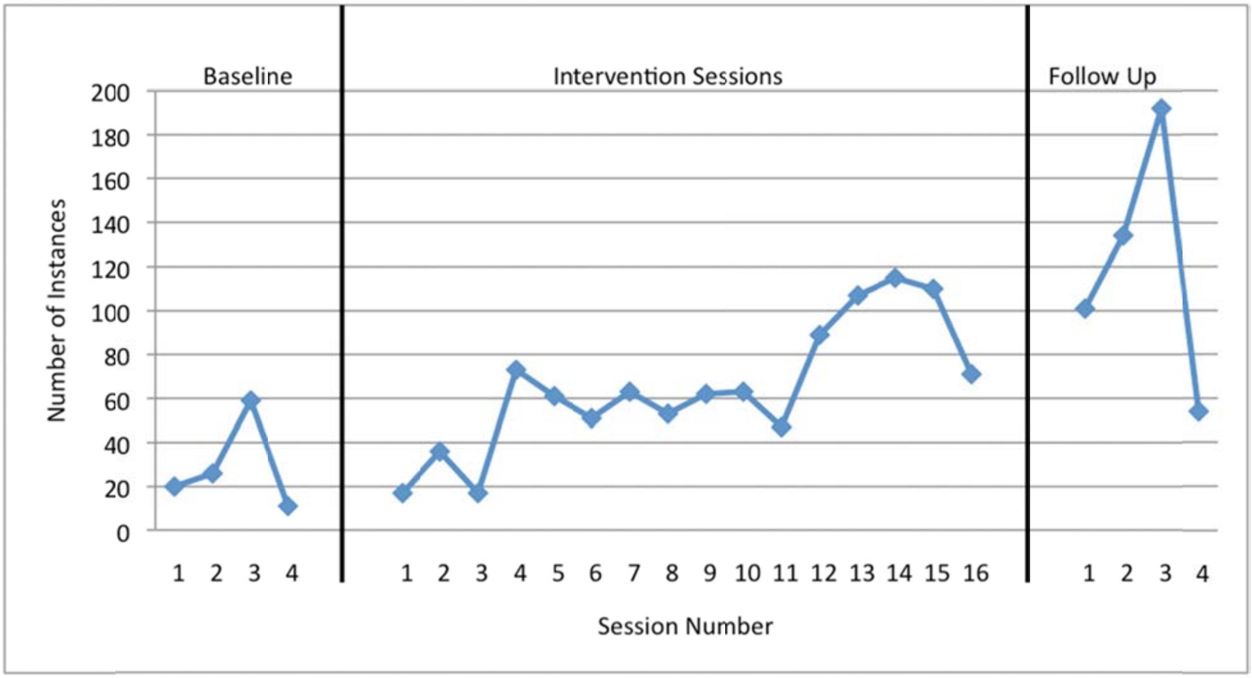


Figure 2. The total number of instances in each session that Abe responded to engagement with an adult.

represented specific distractions that occurred during the intervention. For example, during session 16 Abe became distracted by the ramp that was placed in front of Troy. The ramp was removed and Abe was no longer distracted but the time off task is reflected in the number of interactions.

Social Engagement in the Four Categories. Figure 3 represents the total number of instances from baseline, intervention, and follow-up in which Abe responded to engagement in each of the four categories including language, affect, imitation, and eye contact. Again, there is variation from session to session and across the four categories. Eye contact increased the most from beginning to end. Language, affect, and imitation varied across each session due to various influences such as the activities presented in each session, the materials used, and distracters such as siblings in the room. In session 10 Troy malfunctioned and Abe fixated on looking at Troy and interacted less with the adults. Although performance variability was high from session to session in these three categories, Abe began intervention with almost no behavior in language, affect, and imitation and made general increases throughout the study.

Social Engagement with the Robot. Figure 4 represents the total number of instances during the individual intervention sessions that Abe demonstrated engagement with the robot. There is a general increase in interaction with the robot from the beginning to the end of the study.

Social Engagement with Adult and Robot. Figure 5 represents the number of instances across the 16 sessions that Abe demonstrated engagement with the robot and an adult (one of the clinicians and/or his mother). Abe's interaction with an adult and the robot generally increased from the beginning of the study to the end excluding sessions 15 and 16. In these two sessions,

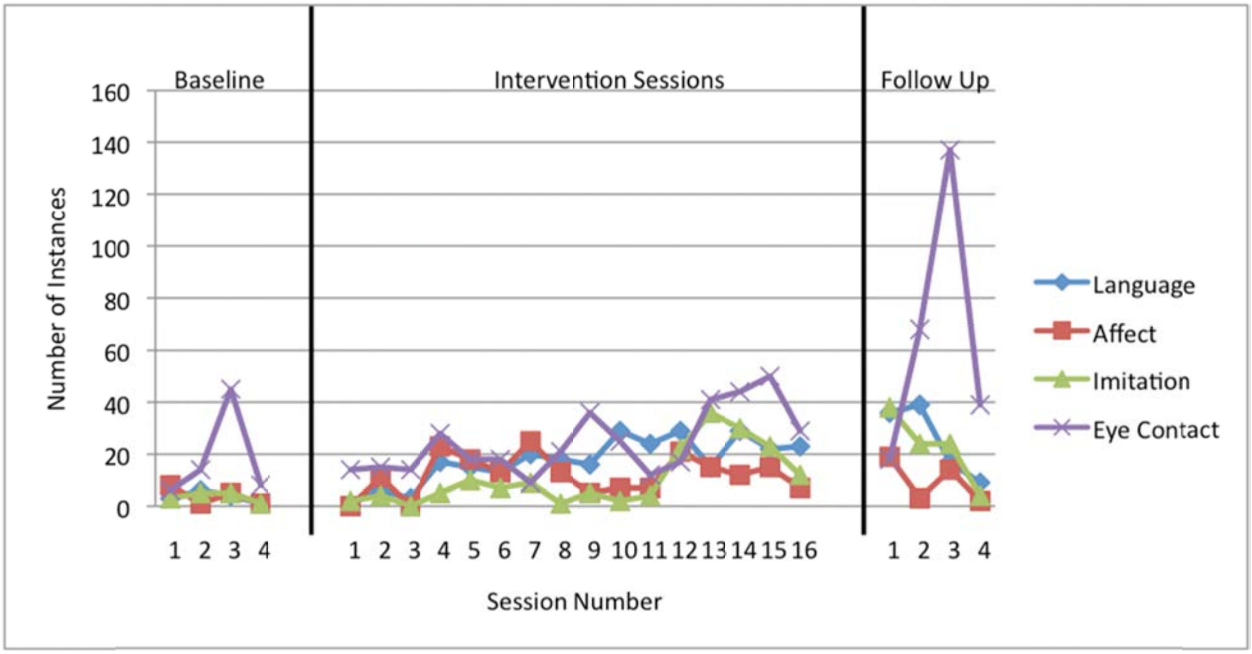


Figure 3. The total number of instances in each session that Abe responded to engagement in each category.

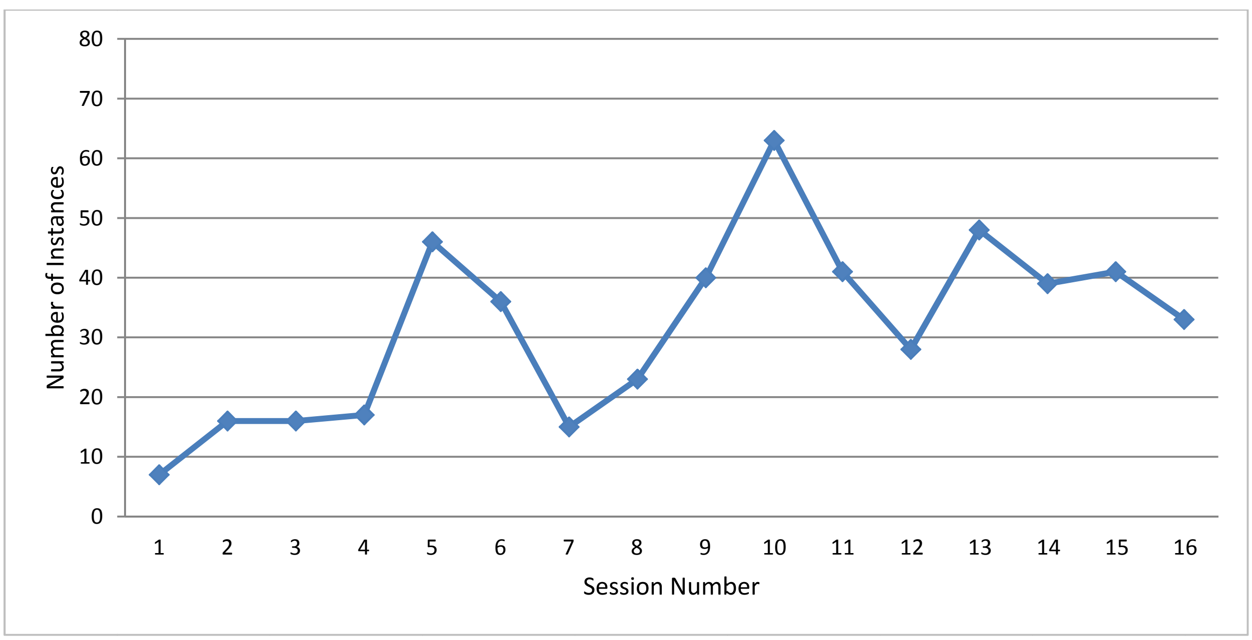


Figure 4. The total number of instances in each session that Abe demonstrated engagement with only the robot.

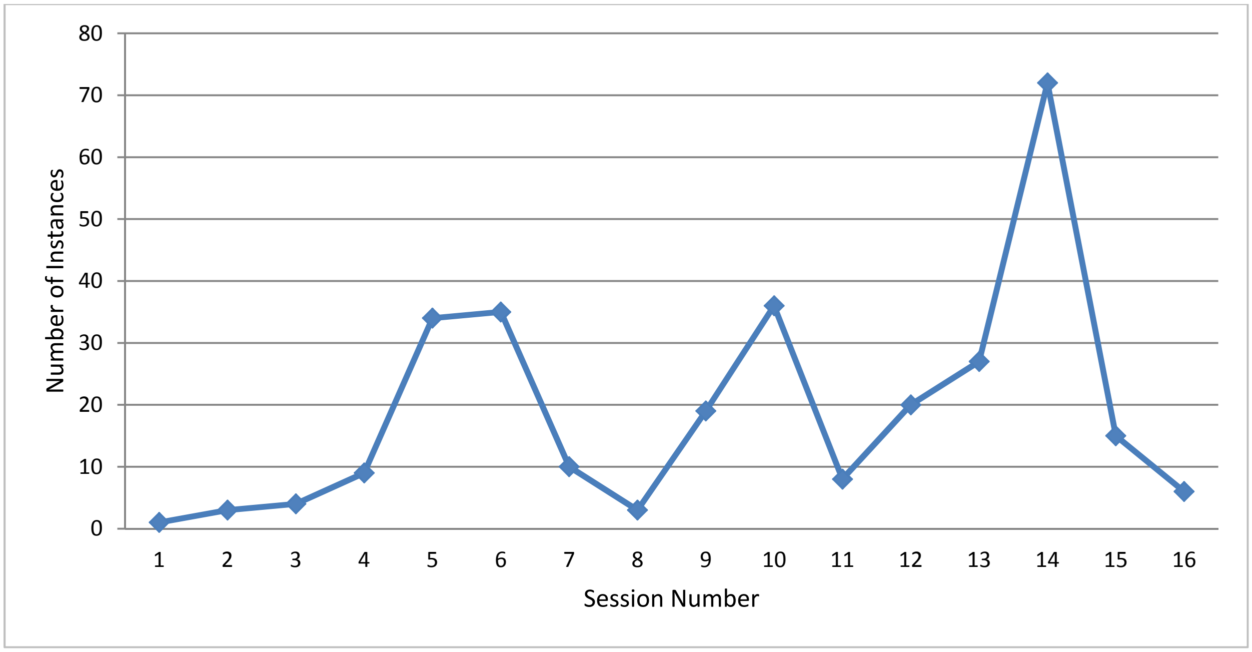


Figure 5. The total number of instances in each session that Abe interacted with an adult and the robot.

Abe seemed to be distracted by broken equipment. Also in session 15, Abe appeared to be distracted by his sister who was taking part in the interaction.

Clark's Performance

Social Engagement with Caregiver and/or the Clinician. Figure 6 represents the total number of instances from baseline, intervention, and follow-up sessions in which Clark responded to engagement with an adult. Clark made general improvement in social engagement with adults from the beginning of the study to the end except for session six and 16. In session six, Clark became distracted often by the open cupboard, toys on the cabinet, his Lego toy, and the lights throughout the session.

Social Engagement in the Four Categories. Figure 7 represents the number of instances during baseline, intervention, and follow-up sessions in which Clark responded to engagement in each of the four categories of language, affect, imitation, and eye contact. All four categories varied one from another and from session to session. The two categories that increased the most from beginning to end were eye contact and language. These two categories also showed general improvement in contrast to affect and imitation, which showed little change during the intervention.

Social Engagement with the Robot. Figure 8 represents the total number of instances through all 16 sessions that Clark demonstrated engagement with only the robot. Clark's engagement with the robot generally increased from the beginning to the end of the intervention.

Social Engagement with Adult and Robot. Figure 9 represents the number of instances through all 16 sessions that Clark demonstrated engagement with the robot and a human. Again, although Clark's social engagement varied from session to session, there was a general increase in interaction with an adult and the robot from beginning to end.

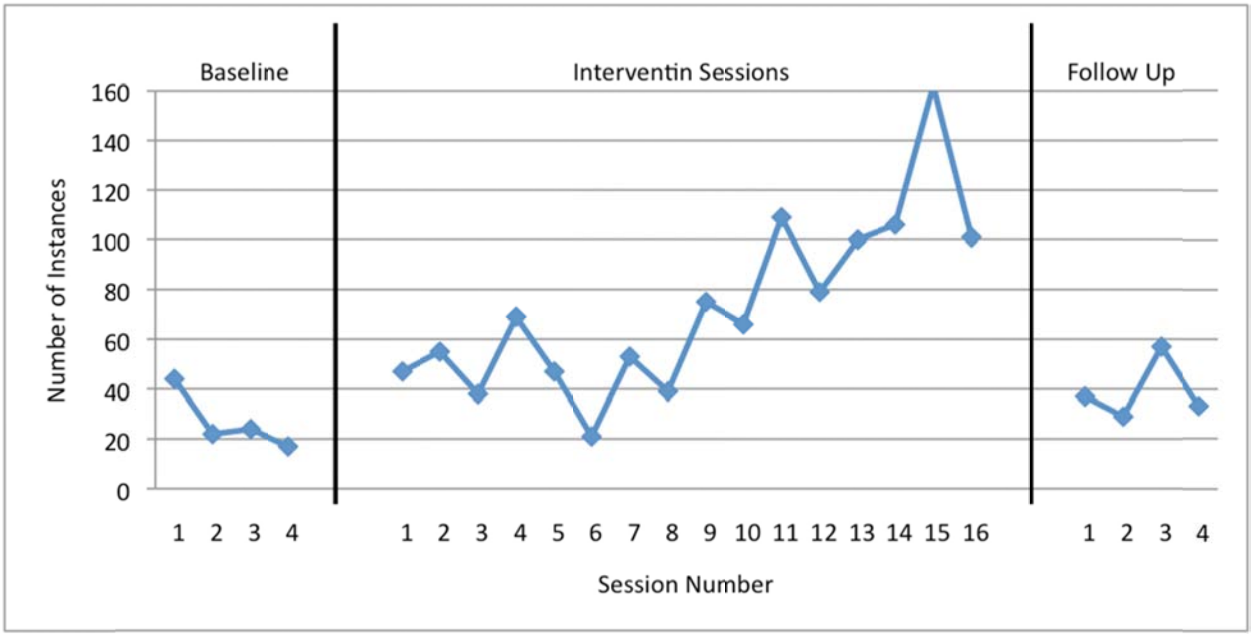


Figure 6. The total number of instances in each session that Clark responded to engagement with an adult.

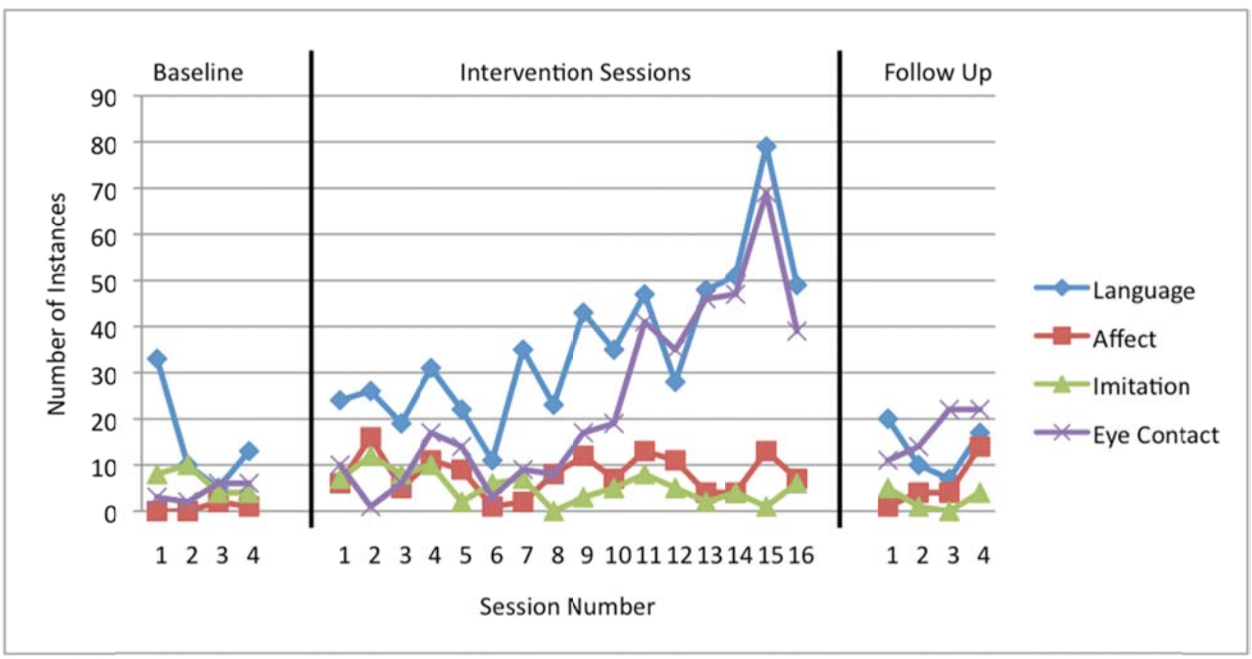


Figure 7. The total number of instances in each session that Clark responded to engagement in each category.

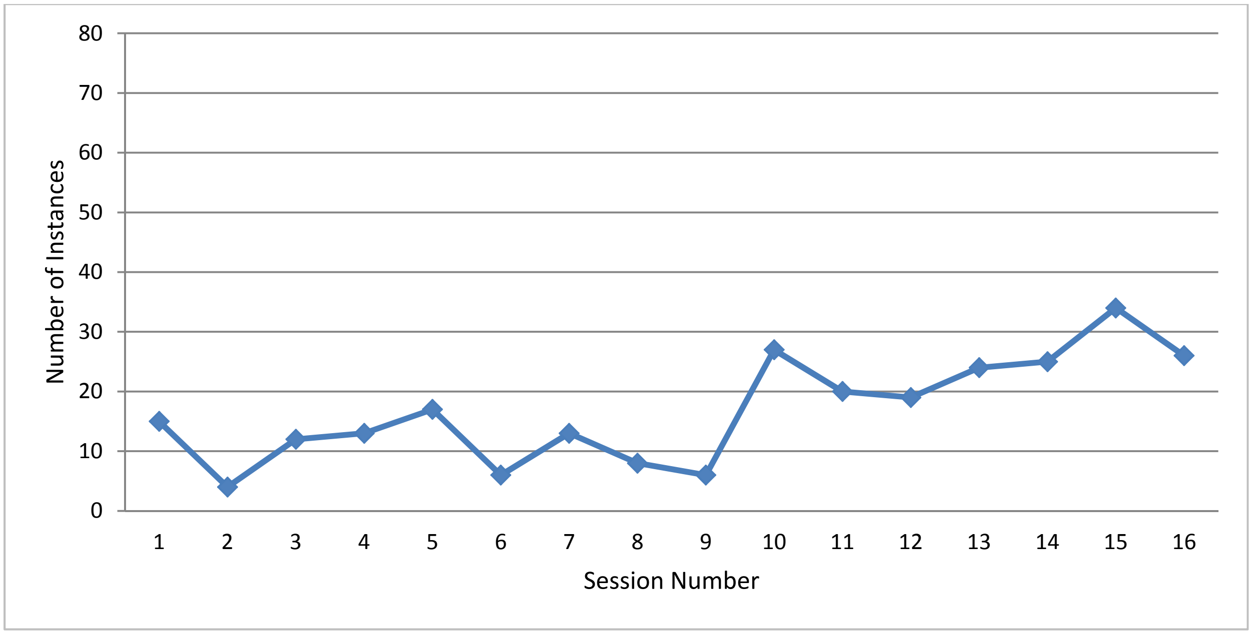


Figure 8. The total number of instances in each session that Clark demonstrated engagement with only the robot.

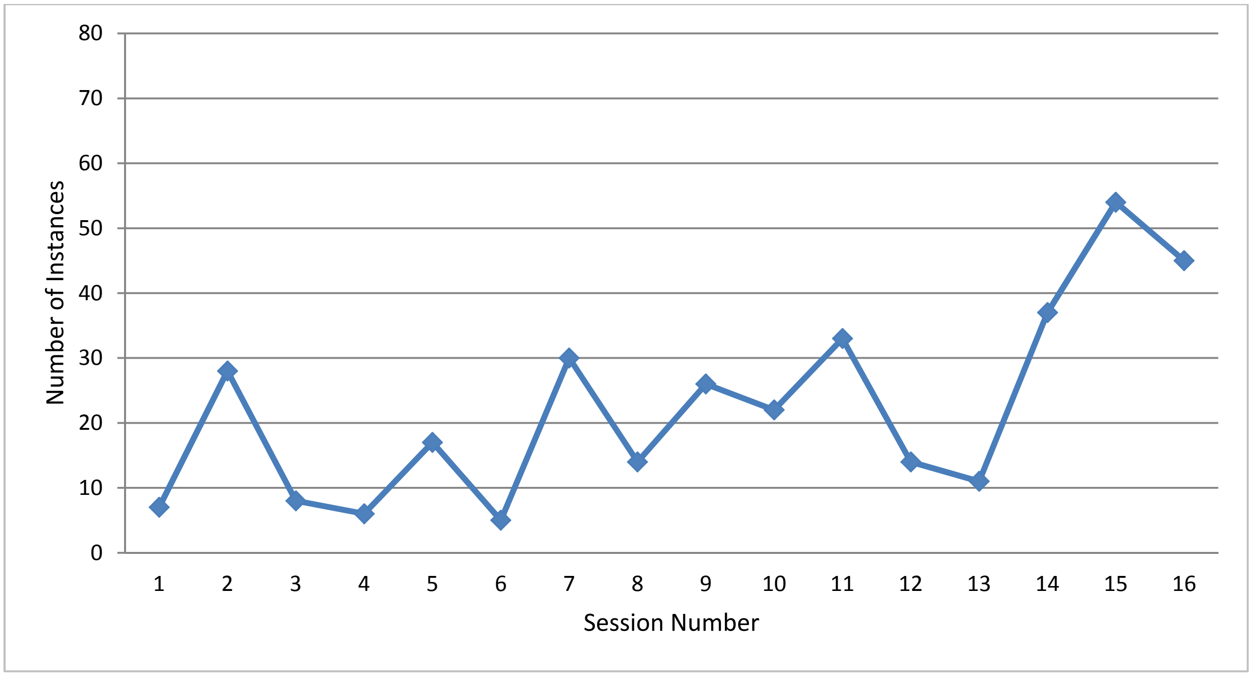


Figure 9. The total number of instances in each session that Clark interacted with an adult and the robot.

Discussion

This study explored the development of joint attention skills in children with ASD as a result of using a humanoid robot in intervention sessions. Traditional intervention was given along with 10-min robot sessions twice a week for a total of 16 sessions. Pre and post sessions were used to gather data before and after intervention to measure behaviors in a triadic interaction, with an unfamiliar adult, with the parent, and with the clinician. This study looks specifically at the responding to interaction behaviors in the robot portion of the 16 intervention sessions. Responding to joint attention behaviors seen in the children were put into different categories including *language, affect, imitation,* and *eye contact.*

The two participants were children with ASD. Abe was 3:7 at the beginning of the study. He was diagnosed with PDD-NOS, hypotonia, language delay, sensory problems, and gross motor delays. The second child, Clark was 7:11 at the beginning of this study. He was diagnosed with ASD and attention deficit hyperactive disorder (ADHD) and communicated with 2-4 word phrases at the beginning of this study. Looking at the baseline sessions, neither boy responded to interaction much differently than he had in the pre-intervention sessions. Throughout the 16 sessions, both boys displayed an overall increase in responding to engagement behaviors to both adults and to the robot. They also appeared to enjoy interacting with the robot from its initial introduction into the intervention.

On an individual basis, Abe responded very well to the robot and increased from almost no instances of responding to interaction in baseline to a substantial amount across 16 intervention sessions. Looking at the different behaviors, eye contact improved the most followed by language. With the two other behaviors, imitation and affect, there was not as big of an improvement from the beginning to the end but these behaviors were not seen at all prior to or at the beginning of the intervention sessions. In observing these sessions, the robot seemed to play an important role in facilitating growth in responding to joint attention. Before the introduction of the robot there was no growth in joint attention behaviors with a semester of traditional intervention. There was general continual increase in responding to joint attention across the 16 interventions.

Clark also responded well to the robot. Initially, Clark produced few behaviors in responding to joint attention in baseline. The behaviors increased substantially across 16 ten-min sessions. Just as Abe increased the most in eye contact and language, Clark also made considerable improvement in these areas as well. No notable improvement occurred with imitation and affect.

During these sessions, the robot seemed to play an important role for Clark as well as Abe in facilitating growth in responding to joint attention but there was variation within the positive slope of behaviors seen from session one to 16 due to several variables. For example, Clark‘s session six showed a marked drop in the number of responding behaviors. In this session, he was distracted by many things such as the open cupboard, toys on the cabinet, his Lego toy, and the room lights.

Although there was some variability in performance, responses to bids for joint attention generally increased in response to the intervention involving the robot for both participants. Each child had low production not only in baseline, but also during the previous semester of traditional intervention. Besides improvement in the specific responding to joint attention skills measured in this study, the graduate clinicians observed other skills that were not present before. Both Abe and Clark were observed to change their restricted interests and repetitive play. For example, both children participated in play interactions that they had not done before and used toys in appropriate ways that were previously used inappropriately. Abe, began using pictures to represent objects or individuals and to request. Observational data suggested that both boys continued to show positive affect and continued to respond to engagement following the 10 min segment with the robot. They also generalized social greetings, such as saying and waving hello and goodbye, to settings outside of treatment sessions (Acerson, 2011). Overall, the robot was a positive experience for these two boys as indicated by their positive affect when with the robot, desire to see the robot while at the clinic, and positive changes in behavior made throughout the treatment process.

Why these behaviors increased in the interactions with the robot is a matter of speculation. It may be that the children were more emotionally engaged in interactions with the robot, and thus more responsive to the intervention. Both boys seemed to enjoy interacting with the robot and to be motivated by the robot to interact with other individuals. This positive affect may have created a motivating environment for the children to learn new skills. It is also possible that some aspect of the robot itself could have contributed to increased behaviors. There are several possibilities to why the children may have responded more favorable to the robot including (a) providing external stimuli to enhance targeted behaviors (Goldsmith & LeBlanc, 2004); (b) engaging the children in the interactions and motivating the children to interact (Giannopulu & Pradel, 2010; Robins, Dickerson, Stribling, & Dautenhahn, 2004); (c) providing a combination of appealing visual and auditory language stimuli (Bosseler & Massaro, 2003); or (d) providing enjoyment which offered a better learning environment (Wainer et al., 2010). Whatever the reason for these findings, it is unlikely that natural development or traditional intervention alone was the reason for improved skills. Both boys had been seen for some time in the BYU clinic before the introduction of the robot. During this time limited change in behavior was noted.

Suggestions for Future Research

The results of using a humanoid robot in joint attention intervention with two children was highly promising. Before these outcomes can be confidently applied to children with ASD in general, however, this study will need to be replicated with a larger sample using a true experimental design. These enhancements will provide more evidence that the observed increase in interactive behaviors was due to the intervention. Additionally, future research should include different robotic intervention configurations to determine what aspects facilitated growth. Traditional and robot intervention were combined in this study and improvements were made as a result of this model. Progress was not seen as a result of traditional intervention alone however. Future research needs to determine what model of therapy results in improvement, whether it is a result of the combination of robot and traditional intervention or robot intervention alone.

In delivering the intervention, there are several factors that might be controlled to make the intervention more effective. For example, factors such as robot malfunctions, extra individuals in the room (e.g., siblings), extra visible toys in the room, and the Lego toys brought from the traditional therapy all seemed influential. In a future study, it might be beneficial to more carefully control these types of variables. In future studies, these factors could be controlled by either elimination or careful data collection. Controlling these factors as much as possible by coding them alongside the behaviors measured would provide an opportunity to compare the two by looking at the fluctuation of behaviors compared to possible influential factors.

Conclusion

Abe showed improvement from baseline to intervention in responding to bids for joint attention with adults. Eye contact increased the most in responding to joint attention while language, affect, and imitation varied across each session. This was a notable improvement from the pre-assessment session during which almost no behaviors were observed in these areas. Abe's response to bids for interaction with the robot also generally increased across the 16 intervention sessions. Clark also improved from session one to 16 in responding to bids for joint attention with adults with variation. There was a drop in responding behaviors in session six and 16, which could be due to distractions in the room. Language and eye contact improved the most from the beginning to end. Affect and imitation showed little change during intervention. Clark also generally improved in responding to bids for interaction with the robot across the 16 sessions. These results (along with other results from the overall study) indicate that responses to bids for joint attention increased in response to the intervention involving the robot for both participants with ASD. More research is needed to better verify the influence of a humanoid robot in intervention on joint attention behaviors including imitation, verbalization, affect, and eye contact.

References

Acerson, A. K. (2011). *The effects of the use of a humanoid robot on social engagement in two children with autism.* (Unpublished master's thesis). Brigham Young University, Provo, Utah.

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Bakeman, R., & Adamson, L. B. (1984). Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Development*, *55*, 1278-1289.

Belmonte, M. K., Allen, G., Beckel-Mitchener, A., Boulanger, L. M., Carper, R. A., & Webb, S. J. (2004). Autism and abnormal development of brain connectivity. *The Journal of Neuroscience, 24*(42), 9228-9231. doi: 10.1523/JNEUROSCI.3340-04.2004

Bosseler, A., & Massaro, D. W. (2003). Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of Autism and Developmental Disorders, 33,* 653-672.

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*, 169-175. doi:10.1002/mrdd.20036

Calandrella, A. M., & Wilcox, J. M. (2000). Predicting language outcomes for young prelinguistic children with developmental delay. *Journal of Speech and Hearing Research, 42*, 915-924.

Campolo, D., Taffoni, F., Schiavone, G., Laschi, C., Keller, F., & Guglielmelli, E. (2008). A novel technological approach towards the early diagnosis of neurodevelopmental disorders. *Engineering in Medicine and Biology Society*, 4875-4878. doi:10.1109/IEMBS.2008.4650306

Duguette, A, Michaud, F., & Mercier, H. (2008). Exploring the use of a mobile robot as an imitation agent with children with low-funcitoning autism. *Autonomous Robots*, *24*(2), 147-157. doi:10.1007/s10514-007-9056-5

Feil-Seifer, D., & Mataric, M. J. (2009). Toward socially assistive robotics for augenting interventions for children with autism spectrum disorder. *Springer Tracts in Advanced Robotics, 54*, 201-210. doi:10.1007/978-3-642-00196-3_242

Giannopulu, I., & Pradel, G. (2010). Multimodal interactions in free game play of children with autism and mobile toy robot. *NeuroRehabilitation, 27*, 305-311. doi:10.3233/NRE-2010-0613

Goldsmith, T. R., & LeBlanc, L. A. (2004). Use of technology in interventions for children with autism. *Journal of Early and Intensive Behavioral Intervention*, *1*(2), 166-178.

Hansen, M. M. (2011). *The effect of a treatment program utilizing a humanoid robot on the social engagement of two children with autism spectrum disorder.* (Unpublished master's thesis). Brigham Young University, Provo, Utah.

Heimann, M., Nelson, K. E., Tjus, T., & Gillberg, C. (1995). Increasing reading and communication skills in children with autism through an interactive multimedia computer program. *Journal of Autism and Developmental Disorders, 25,* 459-480.

Jones, E. A. (2009). Establishing response and stimulus classes for initiating joint attention in children with autism. *Research in Autism Spectrum Disorders, 3*(2), 375-389. doi: 10.1016/j.rasd.2008.08.004

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

Kasari, C., Gulsrud, C. A., Wong, C., Kwon, S., & Locke J. (2010). Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *Journal of Autism and Developmental Disorders*, *34*, 1045-1056. doi: 10.1007/s10803-010-0955-5

Keller, F., & Persico, A. M. (2003). The neurobiological context of autism. *Molecular Neurobiology*, *28*(1), 1-22. doi: 10.1385/MN:28:1:1

Kozima, H., Nakagawa, C., & Yuriko, Y. (2005). Interactive robots for communication-care: A case-study in autism therapy. Proceedings of the *IEEE International Workshop on Robots and Human Interactive Communication*, Nashville, TN, 341-346.

Lord, C., Rutter, M. L., & Dilavore, P. C. (1999). *Autism diagnostic observational scale*. Los Angeles, CA: Western Psychological Services.

McCathren R. B., Yoder, P. J., & Warren, S. F. (1999). Pre-linguistic pragmatic functions as predictors of later expressive vocabulary. *Journal of Early Intervention, 22,* 205-216.

Moore, M., & Calvert, S. (2000). Brief Report: Vocabulary acquisition for children with autism: Teacher or computer instruction. *Journal of Autism and Developmental Disorders*, *30,* 359-362.

Mundy, P., Block, J., Delgado, C. Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development, 78*(3), 938-954.

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and Developmental Disorders*, *20*(1), 115-128.

Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the social deficits of autism: The contribution of non-verbal communication measures. *Journal of Child Psychology and Psychiatry, 27*(5), 657-669.

Pierno, A. C., Mari, M., Lusher, D., & Castiello, U. (2008). Robotic movement elicits visuomotor priming in children with autism. *Neuropsychologia*, *46*(2), 448-454. doi:10.1016/j.neuropsychologia.2007.08.020

Prelock, A. P. (2006). *Autism spectrum disorder: Issues in assessment and intervention*. Austin, TX, Pro-ed.

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

Robins, B., Dickerson, P., Stribling, P., & Dautenhahn, K. (2004). Robot-mediated joint attention in children with autism. *Interaction Studies, 5*(2), 161-198.

Seibert, J. M., Hogan, A. E., & Munday, P. C. (1982). Assessing interactional competencies: The Early Social Communicaton Scales. *Infant Mental Health Journal, 3*, 244-245.

Silver, M., & Oakes, P. (2001). Evaluation of a new computer intervention to teach people with autism or asperger syndrome to recognize and predict emotions in others. *Autism, 5*, 229-316.

Taylor, B. A., Levin, L., & Jasper, S. (1999). Increasing play-related statements in children with autism toward their siblings: Effects of video modeling. *Journal of Developmental and Physical Disabilities, 11*, 253-264.

Tomasello, M., & Farrar, F. J. (1986). Joint attention and early language. *Child Development, 57*, 1454-1463.

Volker, M. A., & Lopata, C. (2008). Autism: A review of biological bases, assessment, and intervention. *School Psychology Quarterly, 23*(2), 258-270. doi:10.1037/1045-3830.23.2.258

Wainer, J., Ferrari, E., Dautenhahn, K., & Robins, B. (2010). The effectiveness of using a robotics class to foster collaboration among groups of children with autism in an exploratory study. *Personal and Ubiguitous Computing, 14*(5), 443-455. doi:10.1007/s00779-009-0266

Wimpory, D. C., Hobson, R. P., Williams, J. M. G., & Nash, S. (2000). Are infants with autism socially engaged? A study of recent retrospective parental reports. *Journal of Autism and Developmental Disorders, 30*(6), 525-536.

Appendix A

Annotated Bibliography

Acerson, A. K. (2011). ***The effects of the use of a humanoid robot on social engagement in two children with autism.*** **(Unpublished master's thesis). Brigham Young University, Provo, Utah.**

Purpose of the study:
This thesis was part of the same overall project as the current study. This research took place prior to the current study and its purpose was to investigate the outcomes of intervention with a robot on social engagement in children with ASD comparing the baseline to the follow up data.

Method:
Participants:
Acerson used two male children with ASD who exhibited deficits in social and communication behaviors, joint attention behaviors, and language functioning. Both were participating at the BYU Speech and Language Clinic prior to the study.

Procedures/Assessment Instruments:
Acerson explored the use of robots in social engagement therapy for children with ASD, referred to as Alex and Chris, by providing 10-15 minute interaction with a humanoid robot integrated into more traditional therapy sessions. A series of different assessments were used including child-parent play assessment, child-clinician play assessment, unfamiliar adult play assessment, and triadic interaction assessment. For this particular part of the study, Acerson analyzed the child-parent play and the child-clinician play assessments from before and after the intervention. Behaviors that were observed and analyzed included language, affect, imitation, and eye contact in both initiating and responding categories.

Results:
Alex exhibited an increase in frequency and duration of initiating and responding behaviors during both child-clinician and child-parent assessments. Chris demonstrated an increase or maintenance in all targeted behaviors in either responding to or initiating engagement when child-clinician pre and post treatment assessment were compared. He also displayed a decrease or no increase in 75% of the targeted behaviors in the child-parent condition.

Conclusions:
Chris maintained the amount of behaviors across both assessments with a slight increase in some behaviors during clinician-child post intervention. In the parent-child post-intervention session he maintained or decreased slightly in the number of engagement behaviors compared to the pre-intervention session. The other boy, Alex, demonstrated an increase in the number of engagement behaviors in both categories of responding and initiating in both post-intervention sessions. He also demonstrated a decrease in the amount of non-engagement behaviors in the post-intervention sessions.

Relevance to current work:

This study is relevant to the current study because both are part of the same pilot study. Acerson's research occurred prior to the current study and included the same participants and methods.

Aylward, E. H., Minshew, N. J., Field, K., Sparks, B. F., & Singh, N. (2002). Effects of age on brain volume and head circumference in autism. *Neurology, 59*(2), 175-183.

Purpose of the study:
This article studied the brain size of individuals with ASD using MRIs and comparing this information with typically developing people. Aylward et al. also compared brain sizes with age to see if there was a correlation.

Method:
Participants:
Aylward et al. used 67 people with ASD and 83 control subjects who were considered typical. All individuals were between the ages of eight and 46 and were Caucasian. The control subjects were matched to the individuals with ASD in the areas of age, IQ, sex, race, and socioeconomic status.

Procedures/Assessment Instruments:
To measure the size of the brain, Aylward et al. used MRI scans as well as circumference and head volume. The brain volume was measured using a software program that separated the volume of the brain from cerebral spinal fluid and extracerebral tissue. After the measurements were all taken, the group with ASD was compared to the control group. Brain size was also analyzed according to age.

Results:
There was no difference in brain volume comparing the group with ASD with the control group, but circumference was higher in the group with ASD. When analyzing these data along with age, children with ASD 12 years and younger, had significantly larger brains than the control group.

Conclusions:
Aylward et al. conclude that the brain of a child with ASD develops in a different pattern than that of a typically developing child. Younger children with ASD experience acceleration in brain growth and a decrease later compared to typically developing children whose brains increase.

Relevance to current work:
This study is relevant to the current study because it helped to explain some of the differences between children with ASD and typically developing children. It also revealed some possible underlying causes of ASD.

Bakeman, R., & Adamson, L. B. (1984). Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Development, 55,* 1278-1289.

Purpose of the study:
The purpose of this study was to observe six to 18 month old infants' joint attention when interacting with their mother and peers.

Method:
Participants:
Bakeman and Adamson used 28 infants from six to 18 months. The infants were divided into two groups with even amounts of boys and girls in each. Mothers were, on average, 29.7 years old.

Procedures/Assessment Instruments:
The children were recorded in their homes. The first group was recorded within two weeks before six, nine, 12, and 15 months of age and the second group was recorded two weeks before nine, 12, 15, and 18 months of age. Each recording consisted of an interaction with the mother, an interaction with familiar peers, and by themselves. The infant's behaviors were coded into six categories including (a) *Unengaged*, (b) *Onlooking*, or looking at another's activities, (c) *Persons*, or is engaged but not with the other individual, (d) *Objects*, or the infant is engaged with an object and not the individual, (e) *Passive joint*, or the infant and the other individual are attending to an object but the infant does not seem to be aware of the other individual, (f) *Coordinated joint*, or the infant is engaged in the object and the other individual.

Results:
Infants followed similar developmental behaviors regardless of the individual the infant was interacting. Exceptions to this observation were found for two of the behavior categories, *passive joint* and *coordinated joint*, which appeared more often when the infant was with their mother. These developmental patterns included a decrease in *persons* and an increase in *coordinated joint* as the child grew older. Also, *passive* joint and *coordinated joint* were more likely observed with the infant interacted with their mothers. Last, *objects* and *onlooking* stayed the same as the infants grew older.

Conclusions:
Bakeman and Adamson concluded that communication skills are first learned in social contexts. Mothers play an important role for development of these joint attention skills for infants. They scaffold social interactional exchanges for infants using objects. Even though mothers play such an important role, other willing and able adults create a well-supported context for infants to gain joint attention skills.

Relevance to Current Work:
This study is relevant to the current study because Bakeman and Adamson's study is aimed at observing typical joint attention behaviors in infants. The current study is aimed at remediating joint attention behaviors that are not typically developing in children with ASD.

Belmonte, M. K., Allen, G., Beckel-Mitchener, A., Boulanger, L. M., Carper, R. A., & Webb, S. J. (2004). Autism and abnormal development of brain connectivity. *The Journal of Neuroscience, 24*(42), 9228-9231. doi: 10.1523/JNEUROSCI.3340-04.2004

Purpose of the study:
The purpose of this article was to better explain the connection between neuroanatomy, physiology, genetics, and biochemistry to behaviors in individuals with ASD.

Summary:
Belmonte et al. gathered research on ASD in terms of neuroanatomy, physiology, genetics, biochemistry, and behavior as the basis to determining better intervention targets and to inform theories on typical brain development. Research indicates that ASD is a result of various genetic and environmental issues. Individuals with ASD exhibit various behaviors including deficits in executive function, information processing, theory of mind, and empathy. These behaviors lead to a theory of abnormal neural connectivity. Studies also suggest that genetic patterns of brain organization occur that could place certain individuals at a higher risk for ASD. These individuals often have abnormal connectivity to the cerebellum resulting in abnormal motor, cognitive, and social functioning. Belmonte et al. also studied the abnormal brain development of children with ASD and found that the areas most affected are those that control attention, social behavior, and language.

Conclusions:
Belmonte et al. found connections between genetics and neuropathology, neuroanatomy, neurophysiology, and behavior. These findings have the possibility of being the basis for a better understanding of typical and abnormal brain and cognitive functions.

Relevance to current work:
This study is relevant to the current study because it discussed abnormalities in individuals with ASD including brain activity and behaviors. The current study was aimed at finding a way to target these behaviors through a specialized intervention.

Bosseler, A., & Massaro, D. W. (2003). Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of Autism and Developmental Disorders, 33*, 653-672.

Purpose of the study:
The purpose of this study was to determine if a computer-animated program (Language Wizard/Player) could help kids with ASD learn vocabulary and grammar. This study included two separate experiments.

Method:
Participants:
Seven children with ASD between the ages of seven and 12 were examined in the first experiment. All the children came from a day school program. Each child differed in symptoms and abilities but displayed delays in all areas of academics. During the second experiment, six of the seven original children were included.

Procedures/Assessment Instruments:
The study involved three stages including an initial assessment, training and testing, and then a reassessment 30 days after. In the first experiment vocabulary lessons were given through a

computer program called Language Wizard, which included a computer animated tutor, synthesized speech, images of the vocabulary words, and feedback. Before the study began, each child was trained on how to use the computer and the program. During the instructional sessions, the program performed tasks such as asking the child to follow directions including finding a particular item on the screen or vocalizing a word. The second experiment was aimed at determining whether the knowledge the children gained in the first experiment generalized to other pictures of the words and to the environment outside of the computer. Words were gathered that the children did not know. These words were divided into three groups. All words went through the pre-training process discussed earlier. Among the three sets, one set was trained through the program but the child was tested on both the trained and untrained words. The child was then tested using new images of the vocabulary word. If the child was not successful, training was given for these new images. This was done for all three sets. After training was complete, the children were informally tested in a naturalistic setting to observe whether training had generalized.

Results:
All the children involved in this studied improved. In the first experiment, the students were able to identify more words in the posttest and the test 30 days after compared to the initial test. In the second experiment, all the children were able to generalized the vocabulary learned either immediately or after training.

Conclusions:
The program Language Wizard/Player facilitated vocabulary growth as all children increased in accuracy of identification. Not only did these children learn new vocabulary but they also generalized the vocabulary to new contexts and assessments. These children were not evaluated using the new vocabulary in spontaneous speech. This shows that even though children with ASD recognize words in intervention, they do not necessarily transfer this knowledge to spontaneous speech. This may be because of the nature of the controlled environment. Bosseler and Massaro believed that the computer animated tutor that provided both visual and auditory language better facilitated the language learning versus just having one modality. It was also positive for the children to interact with a computer-animated program because of the popularity of technology, the personified conversational aspects, and the availability of the program.

Relevance to current work:
This study is relevant to the current work because both it involved teaching language to children with ASD using technological advances such as computers and robots.

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,* 169-175. doi:10.1002/mrdd.20036

Purpose of the study:
This article presented information from the recent literature on joint attention in typically developing children and children with ASD. Bruinsma et al. gathered information about intentional communication, initiation of joint attention in typical children, initiation of joint attention in children with ASD, and initiation of joint attention as a predictor behavior.

Summary:
Children with ASD develop joint attention skills later or not at all compared to typically developing children. This delay or absence of joint attention appeared to play a part in the difficulty of acquiring typical language. The literature indicated a strong relationship between joint attention and verbal language. Children with ASD form a heterogeneous group and individual needs must guide intervention, therefore studies about heterogeneity may help in determining these intervention needs. Also, standardized measures and psychometrically reliable measures may help provide the information it takes to produce recommendations concerning different types of joint attention.

Conclusions:
Studies of intentional communication and joint attention for typically developing children and children with ASD showed that there was a complex relationship between the child and their environment. Also, intentional communication was important to the development of later verbal language. It has also been found that secondary maladaptive behaviors might relate to a delay in verbal expressive language. Last, functional speech before five was thought to be a good sign for future language development.

Relevance to the current work:
This article is relevant to the current work because it gave a good overview of initiating joint attention comparing children with ASD and typically developing children. It also explored the idea that joint attention relates to verbal language.

Calandrella, A. M., & Wilcox, J. M. (2000). Predicting language outcomes for young prelinguistic children with developmental delay. *Journal of Speech and Hearing Research, 42*, 915-924.

Purpose of the study:
The purpose of this study was to look at behaviors manifested before children acquired verbal language and then consider the child's receptive and expressive abilities when the children became verbal.

Method:
Participants:
Calandrella and Wilcox studied 25 infants with a mix of developmental delays and their mothers. All these infants met several requirements including making the transition from prelinguistic to symbolic communication in a 12-month period, production of prelinguistic behaviors 95%, production of fewer than three words, and a diagnosis of Down syndrome or other developmental delays at the beginning of the study.

Procedures/Assessment Instruments:
Investigators recorded and analyzed interactions between the infant and their mother three to five times. Each measurement was six months apart. Each time, the child and mother were recorded two times within a two-week period. Behaviors that were coded included intentional nonverbal communication acts and other acts supposed by adults as communication. These acts included

referential gestures, vocalizations that were linked to an object or event along with looking at the mother, and coordinated attention (looking). At the end of the study, the children's verbal and nonverbal language was observed using different criteria.

Results:
Calandrella and Wilcox found that nonverbal communication along with coordinated attention predicted later expressive language. Nonverbal intentional communication was the only behavior in the first video recording that predicted language 12 months later. Intentional communication at the first and second recording predicted symbol use in the third recording. Gestures indicating acts in the second recording were predictive of receptive and expressive language in the third recording and were the only predictor for receptive language.

Conclusions:
Prelinguistic nonverbal communication acts predicted later receptive and expressive language for children with a development delay. Overall, the rate of intentional nonverbal communication at the first recording was predictive of spontaneous word production at the end of the study. At the second recording, intentional communication and gestural indicating rates also predicted later language

Relevance to the current work:
This study is relevant to the current work because it indicated a link between nonverbal communication acts or joint attention acts and later language growth. This study gave good support for the purpose of targeting joint attention skills in children who do not develop these skills on their own.

Campolo, D., Taffoni, F., Schiavone, G., Laschi, C., Keller, F., & Guglielmelli, E. (2008). A novel technological approach towards the early diagnosis of neurodevelopmental disorders. *Engineering in Medicine and Biology Society*, 4875-4878. doi:10.1109/IEMBS.2008.4650306

Purpose of the study:
The purpose of this article was to present a new approach to diagnosing neuro-developmental disorders.

Summary:
Campolo et al. described three technological diagnostic instruments to assess behavior. The first was using a toy to examine grasping skills in infants. The second was using sensors that the child wears to measure spontaneous movement. The third was a cap for assessing familiarizing behaviors in response to audio and visual stimuli. Prototypes of these devices have been given to a few clinics.

Conclusions:
Diagnosing ASD ideally should be done using a multimodal assessment involving perceptual and motor areas. Thus low-cost technology is needed to screen a large number of children. With the continued development of these new instruments, screening for ASD using a multimodal approach will become more accessible and affordable.

Relevance to the current work:
This article reviewed main characteristics of children with ASD. Campolo suggested new ways for diagnosing ASD.

Duguette, A, Michaud, F., & Mercier, H. (2008). Exploring the use of a mobile robot as an imitation agent with children with low-funcitoning autism. *Autonomous Robots, 24*(2), 147-157. doi:10.1007/s10514-007-9056-5

Purpose of the study:
The purpose of this study was to examine behaviors such as imitative play in young children comparing a human mediator to a robot mediator that was capable of predictable, simple movements.

Method:
Participants:
Duguette, Michaud, and Mercier used four children who were each five years of age. Each child was diagnosed with low-functioning ASD with limited language skills and limited symbolic, pretend play. Two children were pre-verbal and two were non-verbal.

Procedures/Assessment Instruments
Duguette et al. set up the experiment by splitting the four children into two groups. Each group had one pre-verbal child and one non-verbal child. One group interacted with a human mediator and the second group interacted with the robot mediator. Each mediator performed similar behaviors in three levels. The first level was facial expressions, the second was body movements and familiar actions with objects or without objects. In the last level, the mediator executed an action and named it using simple words. Each child received three sessions a week for a total of 22 sessions. Each session included all three levels and was structured to have the child imitate the mediator's behaviors.

Results:
Comparing the pre-verbal children to the non-verbal children, the pre-verbal children showed more interest and participation compared to the non-verbal children. Children paired with the robot showed a decrease in repetitive play with their favorite toy and no stereotyped behavior toward the robot. These two children also showed more visual contact and proximity. On the other hand, shared convention did not increase for those children paired with the robot (there were a few exceptions to this general conclusion, including imitation of facial expressions). Also, the pre-verbal child showed better imitation of actions with objects and sustained interactions. This same child also showed emerging interactions in several other areas.

Conclusions:
The results showed that the children paired with the robot increased more in sharing focused attention compared to the children paired with the human in all the imitation play patterns. This information led the researchers to believe that the robot appealed to the children with ASD. On the other hand, the children paired with the robot did not do as well in the areas of imitation of body movements or of familiar actions compared to the children paired with the human. The

researchers concluded that it may be easier for children with ASD to understand communication intent from a human because the robot has limited motor capabilities. The study did conclude that using robots as a tool in intervention for children with ASD showed positive results.

Relevance to the current work:

Duguette et al. studied the behavioral outcomes of a robot mediator on children with ASD. The current study also studied the behavioral outcomes of a robot incorporated into an intervention designed to facilitate joint attention. This article was informative information concerning what did and did not work when using robots in intervention with children with ASD.

Feil-Seifer, D., & Mataric, M. J. (2009). Toward socially assistive robotics for augenting interventions for children with autism spectrum disorder. *Springer Tracts in Advanced Robotics, 54,* 201-210. doi:10.1007/978-3-642-00196-3_242

Purpose of the study:

The purpose of the study was to analyze the potential outcomes on social interaction of children with ASD when interacting with a robot that systematically responded to the child's behaviors compared to a robot that responded randomly.

Method:

Participants:

Feil-Seifer and Mataric studied four children. Three of the children were diagnosed with ASD and one was not. Through the process, one child with ASD dropped from the study. The children were between the ages of 20 months and 12 years.

Procedures/Assessment Instruments:

Feil-Seifer and Mataric used DIR/Floortime therapy to target behaviors. They also incorporated a scenario called *Bubble Play,* which included using a bubble machine attached to a robot with two colorful buttons. When the child pushed one of the buttons, the robot would blow bubbles and turn around in circles. This scenario was designed to promote the child to interact socially with another human. This study used two conditions to evaluate their hypothesis. The first condition was a *contingent* situation where the above *Bubble Play* scenario would take place. The second condition was *random*, where the robot would blow bubbles and turn at random times and not in response to pushing the buttons.

Results:

Overall, the robots had a positive result on the children's social interaction skills. The *contingent* condition had greater positive results compared to the *random* condition. Social interaction behaviors that were observed included speech, gestures, movement and physical contact.

Conclusions:

Feil-Seifer and Mataric concluded that the robot's behavior, in some way, caused the change in the children's social behavior. They believed it was the robot's contingent behavior that influenced the amount of social behaviors in the children.

Relevance to the current work:
Feil-Seifer and Mataric's study is relevant to the current work because it provided foundational information that robots can increase social interaction in intervention.

Gaussier, P. (2004). Toward communication: First imitations in infants, low-functioning children with autism and robots. *Interaction Studies, 5*(1), 45-74.

Purpose of the study:
The purpose of this study was to compare imitation skills and reactions to being imitated in both typically developing children and low-functioning children with ASD. Gaussier also provided general suggestions for important abilities a robot should include.

Method:
Participants:
Gaussier compared imitation in three populations including typically developing children, children with ASD, and robots. This study included 10 typical children (age near two months) and 13 children with ASD (ages three to seven years old).

Procedures/Assessment Instruments:
Mothers and typical children were placed in separate rooms in which they could see and hear each other through video and audio monitors. The mothers were instructed to make and keep contact with their infant. Naturally, the mothers smiled, spoke, looked at the infant, clapped their hands, made faces, and imitated their child among other things to keep the interaction going. This interaction lasted from two to four minutes. Mother and infant imitative behaviors were coded using six lists of items including look, facial expression, head/torso, arm/hand, mouth, and sound. Three of these infants continued to meet with an experimenter twice a week for 10 minutes with the same interaction through audio and video screen only. In the 10-minute sessions, the infant and experimenter had identical sets of toys. For the first five minutes, the experimenter modeled movements including tongue, mouth, and eye movement as well as expressive and non-expressive movements of the face. As the child became capable of complex movements, the experimenter added simple actions. The second half of the session, the experimenter imitated the infant's movements. Children with ASD were also observed in similar conditions twice a week for 10 minutes. These interactions were based on a three-episode procedure. In the first episode, the experimenter modeled simple actions with objects and the child with ASD was then free to imitate or not. In the second episode, the experimenter imitated the actions of the child and in the last episode the experimenter modeled actions again but asked the child to imitate this time.

Gaussier also gave suggestions for developing robots that can learn through imitation and interact through imitation. Particularly, he gave four constructional criteria. First, Gaussier proposed the robot be constructed to learn the associations between perceptions and actions so the robot possesses mechanical complexities and efficient control. The second proposal was to equip the robot with imitative capabilities as a result of ambiguous perception. Third, Gaussier proposed the robot be able to reproduce a complex trajectory performed by humans. Last, the robot can perform either end of the imitation (either imitating or being imitated) and take turns doing so.

Results:

The typical infants' videos were coded and 45 gestural imitations were found. Among the 10 infants in the study, nine imitated something within the interaction but each child was different according to frequency of imitation. The observed imitations included head movements, arm/hand movements, torso movements, facial expressions, and tongue movements. The mothers imitated their infants when the infant made eye contact with their mother. Half of the infants demonstrated reciprocal imitation, which is imitating their mother after she imitated them. Also, it was found that the more imitative the mother was, the more imitative the infant was and vise versa. With the three children that were followed, it was found that three month old infants are able to imitate movements directed at indicated parts of the body along with head positions and face movements. At five months, children were able to imitate movements of the mouth, nose, arms, hands and fingers, and simple actions. At six months, the children were able to imitate familiar actions and unfamiliar actions. On the other hand, at five months the children began to have strong emotional reactions to being imitated (e.g., laughter). At seven months, the children began to react to being imitated such as looking back and forth between themselves and their partner. After nine months, the infants showed intention to imitate. Also at nine months, the children and their partners repeated the same action one after the other which were more and more often initiated by the infants.

Conclusions:

The children with ASD were able to imitate simple familiar actions similar to typically developing children. Comparisons of the mental age of children with ASD and their imitation abilities revealed that the development of imitation was similar to typical developmental patterns. This finding indicated that children with ASD were not particularly impaired in imitation. On the other hand, there was a correlation between the level of imitation and imitation recognition.

Relevance to current work:

Research has shown that imitation is an essential part of learning and social functions. The current study identified the change in frequency of imitation and other behaviors associated with communication. The authors also provided suggestions for building a robot that facilitated imitation skills.

Giannopulu, I., & Pradel, G. (2010). Multimodal interactions in free game play of children with autism and mobile toy robot. *NeuroRehabilitation, 27,* 305-311. doi:10.3233/NRE-2010-0613

Purpose of the study:

The purpose of this study was to observe interactions between children with ASD and robots while in free and spontaneous game play.

Method:

Participants:

Giannopulu, and Pradel used four children ages seven to nine years old with ASD.

Procedures/Assessment Instruments:
Each child participated in five-min sessions in which the robot was placed in the middle of the floor before the child and their tutor entered. Interactions were standardized and contingent upon the child's actions. For example, if the child walked towards the robot, the robot would back away. If the child backed away from the robot, the robot would come closer. Each child was observed and the duration of four behaviors towards the robot analyzed (eye contact, touch, manipulation, and posture).

Results:
The children spent most of their time (more than 79%) playing with the robot. The results for how much contact was made with the robot were similar across all the children and were high. Other observed behaviors including touching, manipulating, and posture varied among the children and show that interactions change over time with the robot.

Conclusions:
The children spent most of their time interacting with the robot. Giannopulu and Pradel concluded that all four children varied in the way that they interacted with the robot on the basis of touch, manipulation and posture, but the amount of time making eye contact was consistent across all four children. With these findings, Giannopulu and Pradel conclude that free and spontaneous game play with robots could be a possible source to help children with ASD generalize learned behaviors including social interaction.

Relevance to the current work:
Giannopulu and Pradel's study relates to the current work because it provided an indication that children with ASD have an interest in robots. It also provided a context in which these children could work on targeted behaviors such as social interaction.

Goldsmith, T. R., & LeBlanc, L. A. (2004). Use of technology in interventions for children with autism. *Journal of Early and Intensive Behavioral Intervention, 1*(2), 166-178.

Purpose of the study:
The purpose of the study was to review the literature on technology incorporated into intervention for children with ASD to provide recommendations for future research in this area.

Summary:
Goldsmith and LeBlanc reviewed technology that could be used to address specific problematic behaviors in children with ASD. First, children with ASD often need external help to initiate, maintain and end a behavior. Technology has been a good source for auditory and tactile prompts. Goldsmith and LeBlanc then reviewed video technology, computer-based intervention, virtual reality, and robotics. Study results on these technological aids were positive.

Conclusions:
The research was consistently positive regarding the incorporation of technology into intervention with children with ASD. The research concluded that technology is a useful tool that can be used in interventions with children with ASD. Research with robots with children

with ASD was also very promising but Goldsmith and LeBlanc suggested that more work needs to be done.

Relevance to the current work:
Goldsmith and LeBlanc's article relates to the current work because it investigated children with ASD and their reaction to technology in intervention. Their article also touched on the promising results of incorporating robots into intervention and supported the idea of further research.

Gray, K. M., Tonge, B. J., Sweeney, D. J., & Einfeld, S. L. (2007). Screening for autism in young children with developmental delay: An evaluation of the developmental behaviour checklist: Early screen. *Journal of Autism and Developmental Disorder, 38*, 1003-1010. doi: 10.1007/s10803-007-0473-2

Purpose of the study:
The purpose of this article was to evaluate an assessment measure for children with developmental problems.

Method:
Participants:
This study used parents of 207 children between the ages of 20 and 51 months who showed characteristics of developmental delay.

Procedures/Assessment Instruments:
The parents of the children completed the Developmental Checklist-Early Screen (DBC-ES) before the child was assessed. The DBC-ES consisted of 17 questions which have been shown to be useful in identifying ASD. An assessment was completed and a diagnosis of ASD was made using the DSM-IV. The efficacy of the DBC-ES was evaluated.

Results:
The results indicated that the DBC-ES had good interrater agreement and internal consistency. High sensitivity was also found but with lower specificity. Overall DBC-ES was found to be a good screening tool for children with suspected developmental delays or ASD.

Conclusions:
The authors emphasized the importance of looking at the psychometric properties of screening tests. They also emphasized not replacing a more complete assessment with a screening measurement. Due to the heterogeneity of ASD, screening tools are going to have high sensitivity and specificity and can not replace an in depth clinical assessments.

Relevance to the current work:
The results of this study provided information for the current study about what kind of tools and criteria are useful in screening for ASD.

Hansen, M. M. (2011). The effect of a treatment program utilizing a humanoid robot on the social engagement of two children with autism spectrum disorder. (Unpublished master's thesis). Brigham Young University, Provo, Utah.

Purpose of the study:
This thesis was part of the same overall project as the current study. This research took place prior to the current study and its purpose was to investigate the outcomes of intervention with a robot on social engagement in children with ASD by comparing baseline to follow up data.

Method:
Participants:
Hansen used two male children with ASD who exhibited deficits in social and communication behaviors, joint attention behaviors, and language functioning. Both were receiving intervention services at the BYU Speech and Language Clinic prior to the study.

Procedures/Assessment Instruments:
This study explored the use of robots in social engagement therapy for children with ASD by providing 10-15 minute interactions with a humanoid robot inserted within 50 min therapy sessions. Before the intervention was initiated, a series of different assessments were completed, including child-parent play assessment, child-clinician play assessment, unfamiliar adult play assessment, and triadic interaction assessment. Hansen analyzed the pre and post assessments of the triadic interaction and unfamiliar adult interaction. In these contexts, behaviors that were observed and analyzed included language, affect, imitation, and eye contact in both initiating and responding.

Results:
Abe demonstrated an increase in 81.3% of targeted behaviors in both the triadic and unfamiliar adult interaction contexts. Clark demonstrated an increase or maintenance in 81.3% of all targeted behaviors in both the triadic and unfamiliar adult interaction contexts. It was also observed that both children combined behaviors more often, including eye contact with language or affect. On the other hand, non-engagement behaviors also increased from all pre to post assessments accept for one child's unfamiliar adult assessment.

Conclusions:
Both children demonstrated an increase in behaviors in all forms of engagement. These children also demonstrated an increase in combing behaviors. On the other hand, non-engagement behaviors also increased. Hansen concluded that this might be because the children needed more time to process and regulate before returning to interaction.

Relevance to the current work:
This study is relevant to the current study because it examined the same participants as the current study. Hansen research occurred prior to the current study and included the same participants and methods. Hansen also conducted the therapy sessions that were analyzed in the current work.

Heimann, M., Nelson, K. E., Tjus, T., & Gillberg, C. (1995). Increasing reading and communication skills in children with autism through an interactive multimedia computer program. *Journal of Autism and Developmental Disorders, 25,* 459-480.

Purpose of the study:
The purpose of this study was to explore the outcomes of using an interactive, child-initiated microcomputer program with children with ASD, children with mixed handicaps, and typically developing children when targeting their reading and communication skills.

Method:
Participants:
This study included 11 children with ASD, nine children with mixed handicaps, and 10 normal preschool children.

Procedures/Assessment Instruments:
All children that participated in this study used this interactive, child-initiated microcomputer program (on average, through 19 sessions in a three to four month span). This program targets communication through verbal, animated, and video feedback. The program consisted of four main divisions including *Individual Words, Creating Sentences, Testing Words,* and *Testing Sentences*. Each child was given a period of time to familiarize themselves with the program before the training began. Throughout the training process, the children were tested three times on their communication and reading skills and observed two times.

Results:
All three groups made progress from the beginning of training to the end. Each group improved through increased vocabulary. These children also showed generalized behaviors apart from the computerized program in word reading, phonological awareness, and sentence imitation. Other notable outcomes included increased enjoyment in the children with ASD. During a follow-up period, the children with ASD and mixed handicaps did not show any significant gains. The typically developing children made improvements regardless of the training program.

Conclusions:
In conclusion, motivating multimedia language and literacy programs can possibly encourage language learning for children with ASD and other handicaps. It is important to be careful in selecting an intervention program for a child. It is also important to look at their motivation and pre-intervention language skills, receptive language age, and global language skills so that realistic goals may be met. The best predictors of improvement were mental age, receptive language age, and global language level.

Relevance to the current work:
Heimann and Nelson's study relates to the current work because it looked at children with ASD and their reaction to technology in intervention. The results of this study indicated that the improvements were made during intervention but gains were not maintained after the conclusion of intervention.

Hughes, J. R. (2008). A review of recent reports on autism: 1000 studies published in 2007. *Epilepsy & Behavior, 13,* 425-437.

Purpose of the study:
The purpose of this study was to review and combine 1000 studies published in 2007 about ASD.

Summary:
This article included 1000 articles that were published in 2007 in medline. All articles came to specific conclusions on the topic of ASD. These conclusions included information on etiology, characteristics, and intervention option for individuals with ASD.

Conclusions:
This article reviewed possible etiologies for ASD including elemental metals, genetics, and central nervous system irregularities. This article also explored the possibility that children with ASD have difficulty with theory of mind due to abnormal mirror neurons. It also explored characteristics of children with ASD including selective attention, repetitive behaviors, cognitive and communicative impairments, and epilepsy. Last, this article explored different therapy options for these children, including medication, robotics, and music.

Relevance to the current work:
This article discussed three key points in the research for ASD including the cause, characteristics, and intervention. The current study explored robotics as a possible intervention option for targeting joint attention skills in children with ASD.

Hughes, J. R. (2009). Update on autism; A review of 1300 reports published in 2008. *Epilepsy & Behavior, 16,* 569-589.

Purpose of the study:
The purpose of this study was to review and combine 1300 studies published in 2008 about ASD.

Summary:
Hughes reviewed 1300 articles on autism that were published in 2008 in medline. The findings of these articles are summarized in this article. All studies included came to specific conclusions on the topic of ASD. These conclusions included information on the etiology, characteristics, and intervention options for individuals with ASD.

Conclusions:
Several conclusions were made after reviewing these articles. The etiology of ASD could be related to problems with the mirror neuron system or impairment with central coherence. This article also explored details of characteristics of ASD including language, sleeping, social and behavioral impairments. This article also covered intervention options including medications, magnetic stimulation, and acupuncture.

Relevance to current work:

This article discussed three key points in the research for ASD including the cause, characteristics, and intervention. The current study explored a possible intervention option for key characteristics in children with ASD including joint attention.

Jones, E. A. (2009). Establishing response and stimulus classes for initiating joint attention in children with autism. *Research in Autism Spectrum Disorders, 3*(2), 375-389. doi: 10.1016/j.rasd.2008.08.004

Purpose of the study:
The purpose of the first study presented in this article was to investigate intervention for children with ASD targeting initiating joint attention skills. The purpose of the second study was to look at joint attention intervention to explore expanding these skills into different settings with different stimuli.

Method:
Participants:
The first study used two children diagnosed with ASD. These two children could make eye contact when prompted and were proficient in responding to joint attention skills but did not have proficient initiating joint attention skills. One child was three years old and the other was almost five. One child from the first study participated in the second study.

Procedures/Assessment Instruments:
The first study provided joint attention intervention to these two children through their special education teacher and an additional assistant. Both the teacher and assistant were continuously trained in applied behavior analysis. Intervention was targeted at teaching gaze alternating, gaze alternating and pointing, and gaze alternating, pointing, and verbalizing in that order. Intervention was conducted once a day. Several toys were provided, some of which could be activated to make noise, movement, or light up. These toys were wired in a way that they could be activated without being touched. This allowed the child to take part in initiating joint attention without the interventionist touching the toy. Each child received a certain number of opportunities to produce joint attention each session. Each opportunity followed a format in which the discriminative stimulus occurred, the correct response was modeled if needed, and necessary consequences were delivered. In the second study, one of the two children was used along with the same interventionist as in the first study. Intervention for this boy was based on three routines (puzzles, games, and lunch time) with peers and the interventionists. With each routine, the child was given opportunities to initiate joint attention as described in the first study but with natural consequences.

Results:
In the first study, both children acquired (a) gaze alternating to initiate joint attention; (b) combined form of gaze alternating and pointing; and (c) the combined form of gaze alternating, pointing, and verbalizing after the intervention. In the second study, after intervention with adults in routines, the child did not generalize his skills to routines with peers. After intervention with peers was implemented, initiating joint attention skills reached mastery across two out of three routines.

Conclusions:
In the first study, the results indicated that a traditional joint attention intervention resulted in increasingly sophisticated initiating joint attention skills. Intervention in the second study was not successful during all peer interactions.

Relevance to the current work:
These two studies relate to the current work because they described and explored initiating joint attention intervention with children with ASD. There were promising results in this study that indicated that joint attention can be increased with intervention.

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:
The purpose of this study was to explore the effectiveness in targeting joint attention and symbolic play in children with ASD.

Method:
Participants:
Kasari, Freeman, and Paparella used 58 children with ASD around the age of three or four.

Procedures/Assessment Instruments:
The 58 children were divided into three groups including a joint attention group, a symbolic play group, and a control group. Each intervention provider was randomly assigned to a treatment procedure and child. The intervention model included applied behavior analysis and developmental procedures of responsive and facilitative interactive methods. At the beginning and end of intervention, each child went through a battery of tests and then was observed interacting with his/her mother. Trained graduate students gave intervention for 30 minutes a day for five to six weeks. The children received about five to eight minutes of discrete trial training on their individual goals. After this, the child participated in semi-structured therapy on the floor using techniques close to milieu therapy.

Results:
Results indicated that the joint attention group improved the most in responding to joint attention. The symbolic play group displayed more types of play and more sophisticated play. These gained behaviors were generalized to interaction with their mother. When interacting with their mother, the joint attention group improved in their initiating joint attention skills and the symbolic play group showed more types of symbolic play and sophisticated play.

Conclusions:
The first conclusion was that joint attention and play skills can be taught to children with ASD. The second conclusion was that these skills could be generalized to environments playing with their caregiver. The final finding was that the child centered approach to intervention was positive in facilitating joint attention with others.

Relevance to the current work:
Kasari et al.'s study relates to the current work because it explored joint attention therapy with children with ASD. This study demonstrated the effectiveness of targeting joint attention in therapy with children with ASD.

Kasari, C., Gulsrud, C. A., Wong, C., Kwon, S., & Locke J. (2010). Randomized conrolled caregiver mediated joint engagement intervention for toddlers with autism. *J Autism Dev Disord, 34,* 1045-1056. doi: 10.1007/s10803-010-0955-5

Purpose of the study:
The purpose of this study was to determine if intervention based on developing joint attention would result in increased joint attention between the child and parent.

Method:
Participants:
In this study, 38 parents and their child with ASD participated. The children were not diagnosed with other syndromes apart from ASD. Half of the group received intervention immediately. The other half received intervention after a delay. The children were from 21 to 36 months old with an average mental age of 19.2 months.

Procedures/Assessment Instruments:
Before the study began, the children were tested using the Mullen Scales of Early Learning and the parents were interviewed using the Autism Diagnostic Interview-Revised. After the initial eligibility testing was completed, the children were separated into two groups including the immediate therapy group, and the delayed therapy group. The children in the immediate therapy group received intervention for eight weeks. The delayed therapy group waited for eight weeks before therapy began. Prior to beginning the study, the children and parents were also video recorded interacting for 15 minutes as well as when the intervention began, at the end of intervention, and 12 months after intervention. These videos were analyzed for the percentage of time the child and parents were engaged as well as for the occurrence of functional and symbolic play acts and joint attention behaviors. The intervention consisted of coaching the parent and child interaction in play routines as well as developmental procedures of responsive and facilitative interaction techniques and applied behavioral analysis by following the child's interests in conversation.

Results:
Kasari et al. found that the follow-through with parent responsibilities was good in this intervention technique and that the children became more engaged in interaction with their parents. The children's abilities improved from only object focused to a higher level of joint attention between people and objects. This intervention facilitated growth in responding to joint attention and play diversity for these children.

Conclusions:
Using this data, Kasari et al. found that joint attention and play skills are built off of the child's ability to engage in joint engagement. The study also found the importance of the parents' commitment to and ability to implement this therapy is critical to the success of the intervention.

Relevance to the current work:
Kasari et al. discussed the importance of joint engagement and found a successful technique to teaching joint engagement, joint attention, and play behaviors. The current study also explored ways in which joint attention behaviors can be improved through robotics.

Keller, F., & Persico, A. M. (2003). The neurobiological context of autism. *Molecular Neurobiology, 28*(1), 1-22. doi: 10.1385/MN:28:1:1

Purpose of the study:
The purpose of this article was to explore the current research on ASD as it relates to neurodevelopment with genetic and non-genetic contributions.

Summary:
Keller and Persico gathered data concerning genetics, neuroanatomy, as well as other functional information to make conclusions and suggest further research. Research has come a long way connecting ASD with chromosomal causes, brain regions, cellular biology, and neurochemistry. Environmental causes are still being researched and results are not conclusive. It is possible that there is a combination of genetic and environmental aspects playing a part in etiology. Development factors are another possible piece to the complex disorder. ASD is multilayered with several layers explaining it. This conclusion may stem from the fact that the research is lacking. It might also reflect the fact that the disorder is complex.

Conclusions:
Keller and Persico draw several conclusions based on the research examined. One conclusion was that there is no single gene responsible for ASD and that besides genetics, ASD is a combination of factors including neurodevelopment mechanisms and neural circuits. Keller and Persico also conclude that ASD evolves from problems in several neural system or several abnormalities in synaptic activity. Keller and Persico suggest a layered approach to ASD in that the first layer is the clinical syndrome of ASD which is a distinct syndrome separate from other disorders, the second is the pathologic-anatomic level, and the third is the molecular genetic level.

Relevance to the current work:
This study relates to the current work because it gave a good overview of what ASD is and possible causes and underlying problems contributing to ASD.

Kozima, H., Nakagawa, C., & Yuriko, Y. (2005). Interactive robots for communication-care: A case-study in autism therapy. Proceedings of the *IEEE International Workshop on Robots and Human Interactive Communication,* Nashville, TN, 341-346.

Purpose of the study:
The purpose of this study was to explore different ways to use a robot in intervention for children with ASD when targeting interpersonal communication.

Method:

Participants:
This study used several children with ASD and several typically developing children to observe their interaction with their robot. Two cases were studied longitudinally. One case was a girl who was six years old who had ASD and Intellectual Disability. The second case was a girl three years of age who also had ASD and Intellectual Disability.

Procedures/Assessment Instruments:
Kozima, Nakagawa, and Yuriko used a creature like robot that has the ability to make expressions indicating attention and emotion for children who are interacting with it. First typically developing children were observed as they interacted with the robot to gather information about typical interactions with the robot. Then, children with ASD were observed with the robot. The robot was put into a playroom and was among other toys scattered in the room and the children could play with the robot whenever they wanted.

Results:
In the first case study, the girl showed interest in the robot but avoided eye contact, from the first session. This girl moved closer and closer to the robot as the sessions continued and eventually started interacting with the robot after about 12 sessions. In the second case study, the girl initially did not show interest in playing with the robot but would occasionally look at it when it made noises. At about session 16, the girl started interacting with the robot. Her interactions included touching it and smiling as well as looking at it and smiling at her mother and the nurse. This girl eventually started playing an imitation game with the robot. For this young girl, the robot provided a means for triadic interaction. Both of these children showed change in their interactional skills through the robot.

Conclusions:
The children demonstrated various behaviors towards the robot including facial expressions and prosocial actions, some of which had never been seen before from the child. As a result of the simple nature to the robot, the children were able to approach it with interest and felt safe. On occasion, the children expanded their interactions from a dyadic to triadic interaction to share pleasure with another human. Also, each child was unique as their interaction developed with the robot. These findings conclude that robots can be used to facilitate interactions in social contexts.

Relevance to the current work:
This study relates to the current work because it provided observational information about social interaction changes made in children with ASD through interaction with a robot. These positive results stem from a robot that responded to the child's interactional attempts.

MacDuff, G. S., Drantz, P. J., & McClannahan, L. E. (2001). Prompts and prompt-fading strategies for people with autism. In C. Maurice, & G. Green (Eds.), *Making a difference: Behavioral intervention for autism* (pp. 37-50). Austin, TX: Pro-Ed.

Purpose of the study:

The purpose of this chapter was to present different prompts and fading techniques that help children with ASD.

Summary:
This chapter outlined different prompts that help children with ASD learn different behaviors. These prompts include verbal prompts, modeling, gestural prompts, photographs and line drawings, manual prompts, and textual prompts. Prompt fading techniques were also discussed in this chapter. These techniques were designed to help children with ASD learn behaviors in the most efficient and successful way possible. Ways to pick the appropriate prompts and fading techniques for each individual were discussed as well.

Conclusions:
Each child with ASD responds to specific prompts differently. It is important to decide on prompts and fading techniques based on the individual's needs. Continual assessment of progress with prompts and fading procedures will help to guide the intervention and prevent dependence on prompts.

Relevance to the current work:
This work relates to the current study because it provided an outline of prompt and fading procedures that help children with ASD in intervention. This information offered background knowledge on how children with ASD learn and what supports are needed for success.

McCathren R. B., Yoder, P. J., & Warren, S. F. (1999). Pre-linguistic pragmatic functions as predictors of later expressive vocabulary. *Journal of Early Intervention, 22*, 205-216.

Purpose of the study:
The purpose of this study was to relate prelinguistic pragmatic function to later expressive vocabulary in children with developmental delays.

Method:
Participants:
McCathren, Yoder, and Warren used 58 toddlers who were taken from a larger longitudinal study. Each child had fewer than three words and showed at least one prelinguistic communicative skill.

Procedures/Assessment Instruments:
At the beginning of this study, the children's pragmatic functions were measured and at the end, 12 months later, their expressive vocabulary was measured. To measure expressive vocabulary, a staff member used a number of toys to elicit communication. A communicative composite was used that consisted of communicative temptations including seven situations that elicited comments and requests, and sharing books.

Results:
At the end of the study, all the children but seven were using words. Only 17/58 of the children used communication acts for social interaction and even less demonstrated these skills more than

once. The average rate of expressive vocabulary was .65 words per minute and the average number of words used by each child was 12.65.

Conclusions:
McCathren, Yoder, and Warren's results indicated that the rate of behavior regulation did not predict later expressive vocabulary. On the other hand, rate of joint attention and communication were correlated with later expressive vocabulary. Joint attention may be correlated to later vocabulary due to the link between joint attention and early social competence or the adult response it produces.

Relevance to the current work:
This study relates to the current work because it provided evidence to support the idea of joint attention correlating to later expressive vocabulary. This idea reinforced the current work in targeting joint attention skills in children who are lacking those prelinguistic behaviors.

Moore, M., & Calvert, S. (2000). Brief Report: Vocabulary acquisition for children with autism: Teacher or computer instruction. *Journal of Autism and Developmental Disorders, 30,* 359-362.

Purpose of the study:
The purpose of this study was to examine the influence of computers on vocabulary growth in children with ASD.

Method:
Participants:
Moore and Calvert studied 14 children with ASD between the ages of three and six. All the children attended the same school.

Procedures/Assessment Instruments:
The children in the study were randomly put into two groups including the behavioral and computer conditions. In the behavioral group, the children were taught simple skills that eventually lead to chaining mastered skills. The simple skills included labeling objects through drill and reinforcement. The computer group was similar to the behavioral group but included sensory reinforcement and features such as color, animation, and sound. Before intervention, each child was given a pretest testing knowledge of a range of nouns. Intervention targeted six nouns that the child didn't know.

Results:
Comparing the behavioral condition with the computer condition, the children were more attentive with the computer than they were with the behavioral condition. The children also learned 74% of their nouns with the computer compared to 41% of their nouns with the behavioral condition. More than half of the children paired with the computer wanted to continue intervention while none of the children paired with behavioral intervention wanted to continue.

Conclusions:

Moore and Calvert suggested that combining attention-getting features and behavioral methods is a good method of intervention for children with ASD. This technology helped to gain the children's attention, motivate them, and enhance learning of new vocabulary. Another conclusion was that there was a correlation between attending and memory for the new nouns. Last, combining behavioral and computer intervention could be a positive influence on vocabulary growth.

Relevance to the current work:
This study is relevant to the current work because it provided positive outcomes of using technology with children with ASD in language intervention. It also discussed the advantages of using technology apart from language including increased attention and motivation.

Mundy, P., Block, J., Delgado, C. Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development, 78*(3), 938-954.

Purpose of the study:
The purpose of this study was to examine joint attention behaviors in infants between the ages of nine and 18 months.

Method:
Participants:
Mundy et al. used 95 typically developing infants in this study. The mothers of these infants were 18 years or older.

Procedures/Assessment Instruments:
The infants were placed in a room with the tester and were presented a number of toys including three wind-up toys, three hand-operated toys, a toy car or ball to play turn-taking games, a hat, comb, and glasses, tickling game, and a book. The tester also attempted to initiate gaze following tests. These tasks involved a nonverbal communication assessment called the ESCS. The infants were also given the Mental Scale of the Bayley Scales of Infant Development – II to describe their general cognitive development, the Renell Developmental Language Scales to test receptive and expressive language, and the MacArthur Communication Development Inventory Short Form Level 2.

Results:
The infants in this study demonstrated similar developmental joint attention patterns across age as well as some individual differences. Individual differences in initiating and responding to joint attention were not correlated within ages, but requesting was related. Also, variations in different points of development for initiating and responding to joint attention were associated with 24-month language outcomes that were not related to general cognitive level. Last, responding to joint attention, initiating joint attention, and responding to behavioral requests all showed a linear increase with age but initiating joint attention bids did not.

Conclusions:

Mundy et al.'s results indicated that joint attention develops systematically through age and that there are also individual differences. Differences in cognitive ability resulted in different amount of joint attention acts at certain ages. Also, responding to joint attention at 12 months and initiating joint attention at 18 months predicted language at 24 months.

Relevance to the current work:
This study relates to the current work because it described typical development of joint attention. With this knowledge, it is possible to compare differences in the development of joint attention in typically developing children and the development of joint attention in children with ASD.

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. ***Journal of Autism and Developmental Disorders, 20*****(1), 115-128.**

Purpose of the study:
The purpose of this study was to examine children's use of gestures to establish joint attention and how these skills connect to later language development in children with ASD.

Method:
Participants:
Mundy, Sigman, and Kasari examined 15 children with ASD. All the children had fewer than five words in their expressive vocabulary. Mundy et al. also used six children with Down syndrome and eight children with intellectual disability with no specific etiology

Procedures/Assessment Instruments:
The initial assessment used nonverbal communication tests such as the Cattell Scales of Infant Intelligence, the Stanford Binet, and the Reynell Language Scales. One year later, the children were tested using a nonverbal communication measure, which included a shorter version of the Early Social-Communication Scales, and the Reynell.

Results:
Children with ASD showed deficits in nonverbal joint attention skills both when initially examined and 13 months later compared to the children with Down syndrome and children with other intellectual impairments. Abilities in gestural joint attention skills predicted language growth in individuals with ASD.

Conclusions:
These children with ASD demonstrated impairment in gestural joint attention. This result suggested that the ability to coordinate attention between other people and objects using gestures is important for the development of language and is important to target in early language development.

Relevance to the current work:
This study is relevant to the current work because it revealed the importance of targeting joint attention in intervention for nonverbal children with ASD. The current work was aimed at targeting joint attention behaviors in children with ASD in order to better enhance language.

Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the social deficits of autism: The contribution of non-verbal communication measures. *Journal of Child Psychology and Psychiatry, 27*(5), 657-669.

Purpose of the study:
The purpose of this study was to compare children with ASD to typically developing children and a group of children with intellectual disability with respect to their nonverbal communication and object play skills.

Method:
Participants:
In this study, 18 children with ASD were used ages 34 to 75 months old. A group of 18 intellectually disables children were used, nine with Down syndrome and nine with unknown etiology. These children were matched with the children with ASD on age, mental age, and the level of their mother's education. There was also a group of typically developing children.

Procedures/Assessment Instruments:
All the children were assessed across three sessions. The children were first assessed using the non-verbal social-communication measure and the Cattell Scales of Infant Intelligence or Stanford-Binet. In the second session, each child was tested using an unstructured play task, the Reynell Language Scales. In the last session, the children were assessed using a structured play task.

Results:
Throughout these three assessments, the children with ASD exhibited deficits in higher developmental behaviors of social interaction and requesting. Specifically, these children exhibited shorter turn-taking sequences, responded less to invitations compared to the group with intellectual disabilities, produced less eye contact compared to the typically developing children, and less pointing behaviors than both groups. On the other hand, children with ASD did not exhibit deficits in eye contact and reacted more appropriately to being tickled than children with intellectual disabilities. The children with ASD also exhibited gestural requests for social routines. The children with ASD appeared to follow simple commands, and combined eye contact and gesture to obtain an object at the same rate as the children in both of the other comparison groups. Although the children with ASD exhibited deficits in object play, the most prominent deficit these children exhibited was in the production of nonverbal indicating behaviors.

Conclusions:
Children with ASD lacked higher-level social interaction and requesting behaviors. The authors concluded that a deficit in non-verbal indicating skills was a significant indicator of children with ASD.

Relevance to the current work:
This study relates to the current work in that it provided evidence in support of targeting nonverbal behaviors in intervention for children with ASD. This article discussed several

aspects of language and play skills and compared these skills in children with ASD to typically developing children and children with intellectual disorders.

Ozonoff, S., Pennington, B., Rogers, S. J. (1991) Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry, 32*(7), 1081-1105.

Purpose of the study:
The purpose of this study was to identify areas of difficulty in individuals with high functioning ASD.

Method:
Participants:
Two groups were used in this study including a group with ASD and a control group of individuals without ASD. The individuals in this study ranged in age from eight to 20 years. All participants had typical IQ scores. The control group was matched with the individuals with ASD on age and sex.

Procedures/Assessment Instruments:
Measurements were taken on all individuals in the areas of emotion perception, theory of mind, executive function, and discrimination using several different tasks. Results of the tasks were compared between the group with ASD and the control group.

Results:
Results indicated that children with high-functioning ASD have deficits in executive function, theory of mind, emotion perception and verbal memory. They did not perform differently on spatial tests and IQ tests.

Conclusions:
The authors concluded that deficits in the prefrontal function may be the cause of the main symptoms of ASD. On the other hand, not all of the symptoms of ASD can be tied to prefrontal impairment.

Relevance to the current work:
This study relates to the current work because it provided information about the areas of deficits in and possible cause of ASD. This information provided background knowledge about areas in which children with ASD need support and possible intervention.

Philofsky, A., Fidler, D. J., Hepburn, S. (2007). Pragmatic language profiles of school-age children with autism spectrum disorders and williams syndrome. American Journal of Speech-Language Pathology, 16, 368-380. doi: 10.1044/1058-0360(2007/040)

Purpose of the study:

The purpose of this study was to describe pragmatic functions of children with ASD compared to children with Williams syndrome as well as to investigate whether standardized tools can distinguish two groups of children with differing pragmatic difficulties.

Method:
Participants:
A total of 62 parents of children with ASD, Williams syndrome and typical development were used in this study.

Procedures/Assessment Instruments:
Parents of each child were given the VABS parent interview that explored their child's adaptive behaviors. The child also participated in an ASD diagnostic assessment. Parents of each of the children also completed the Children's Communication Checklist – Second Edition (CCC-2) to assess their children's pragmatic abilities.

Results:
Results showed that the children with ASD and with Williams syndrome demonstrated impairment in both communication and pragmatic skills. There were differences in each group on pragmatic functioning. It was found that the children with Williams syndrome were not as severely impaired as the children with ASD on measures of their pragmatic language skills, coherence, stereotyped language, nonverbal communication, and social relations. The two groups appeared to perform similarly on other subtests of the CCC-2.

Conclusions:
The CCC-2 is an appropriate measure to identify pragmatic characteristics for children with ASD and Williams syndrome.

Relevance to the current work:
This study provided information on the pragmatic functions of children with ASD. The current study examined social communication deficits in children with ASD and therefore information on pragmatic functioning provided important background knowledge about children with ASD.

Pierce, K., & Courchesne E. (2001). Evidence for a cerebellar role in reduced exploration and stereotyped behavior in autism. *Biological Psychiatry, 49*(8), 655-664. dio: 10.1016/S0006-3223(00)01008-8

Purpose of the study:
The purpose of this study was to connect findings on ASD and cerebellar abnormalities.

Method:
Participants:
This study examined 14 children with ASD and 14 typically developing children.

Procedures/Assessment Instruments:
Before participating in the study, each child underwent an MRI to look at areas of interest in the brain. The children participated in eight sessions where they were put in a room with several

containers and told to play. The play behaviors were recorded and coded for the amount of time the children were exploring, the number of containers explored, and stereotyped movements.

Results:
Results showed that the children with ASD spent less time exploring and explored fewer containers compared to typically developing children. Decreases in exploration related to neurological structure as follows. First, decreased exploration correlated with the amount of cerebellar hypoplasia of vermal lobules VI-VII in the children with ASD. Stereotypes behaviors were positively correlated with frontal lobe volume and negatively correlated with areas of cerebellar vermis lobules VI-VII.

Conclusions:
These findings concluded that decreases in the amount of exploration and repetitive behaviors could have developmental repercussions. Exploring is an important behavior and without these behaviors opportunities for learning could be missed.

Relevance to the current work:
This study explored characteristics of children with ASD that could possibly result in loss of learning of important behaviors. This information was related to the current study because we aimed to improve behaviors that children with ASD lack.

Pierno, A. C., Mari, M., Lusher, D., & Castellio, U. (2008). Robotic movement elicits visuomotor priming in children with autism. *Neuropsychologia, 46*(2), 448-454. dio: 10.1016/j.neuropsychologia.2007.08.020

Purpose of the study:
The purpose of this study was to explore the possibility of robots improving interaction with children with ASD. Pierno et al. compared imitation in children with ASD to imitation in typically developing children.

Method:
Participants:
Twelve children (six boys and six girls between the age of 10 and 13) with high functioning ASD were examined. Also included in this study were 12 age and gender matched, typically developing peers. A human model was also used in the study and was also a typically developing 12 year old.

Procedures/Assessment Instruments:
Each participant in this study observed either a human or a robot perform simple actions (e.g., to pick up an object). Then the participants were asked to perform this same task, but were not specifically asked to imitate the actions seen. Controls were also included in this study in which the participants were asked to perform the movement task without any prior preparation. In the human to human interaction, two participants, a model and an observer were seated at a table. The model and observer first put their right hand on the starting switch, then a signal was given to the model to begin. The model would then perform a reach-to-grasp action towards a spherical plastic object. As soon as the action was completed, a sound was presented. This

sound indicated that the child participant should begin the task. The participants were not asked to imitate the action but to complete the reach-to-grasp action toward the object. The human to robot interaction was the same as the human to human interaction but with a robot that was controlled by the experimenter through software. To measure the movements of the participants, markers were attached to the finger and thumb. These markers measured the grasp of each participant or the time of the maximum grip opening. It also measured the time between the release of the starting switch and the time for which the participants' hands grasped the object. Four cameras measured the markers movement.

Results:
Pierno et al. found that the participants with ASD on average had shorter duration both for the time to peak velocity and time to maximum grip opening for the interactions with the robot versus the human and control conditions. It was also concluded that there were no differences between the children with ASD and normally developing children for the control conditions. There was also no difference in which training the child with ASD or normally developing child received regarding movement invitation time.

Conclusions:
A significant finding was that the children with ASD showed consistent difficulty for the human condition and consistent ease for the robot condition. The opposite was found for the normally developing children. This study provides evidence that children with ASD can learn imitative behaviors using robot interaction. Results showed that children with ASD performed better when observing the robot perform the task versus a human performing the task.

Relevance to the current work:
Pierno et al. produced several theories to explain the results of this study. One that is relevant for this study was the idea that the use of robots may trigger an automatic imitative mechanism in children with ASD. This could potentially provide children a means of learning skills for language and communication in therapy.

Prelock, P. A. & Contompasis, S. H. (2006). Autism and related disorders: Trends in diagnosis and neurobiologic considerations. In P. Prelock (Ed.), *Autism spectrum disorder: Issues in assessment and intervention* (pp. 3-63). Austin: Pro-ed.

Purpose of the study:
The purpose of this work was to describe ASD, the characteristics associated with the disorder, the range in the spectrum, and prevelence.

Summary:
In this chapter the authors discussed the rising prevelence of ASD. This work also described different disorders associated with pervasive developmental disorders. Diagnosis of ASD is also discussed. The authors then explore ASD in combination with other disabilities.

Conclusions:

Prelock and Contompasis provided useful information on ASD including details on specific problems and characterstics that define the disorder.

Relevance to the current work:
This work relates to the current study because it provided information about diagnosis and characteristics of ASD.

Rapin, I. (2001). Autistic children: Diagnosis and clinical features. *Pediatrics, 87*(5), 751-760.

Purpose of the study:
The purpose of this article was to define ASD, describe the etiology, characteristics, and development of individuals with ASD.

Summary:
ASD is a disorder of brain function with etiologies associated with genetic and nongenetic factors. ASD first appears in preschool years and is manifested as problems in socialiability, communication, and individual interests with a wide range of severity. There is also a wide range in intelligence in individuals with ASD. Children with ASD all have language difficulties in earlier years.

Conclusions:
The author concluded that there was a wide range of ability in individuals with ASD in severity, intelligence, and characteristics.

Relevance to the current work:
This article provided an overview of ASD including the cause, diagnosis, symptoms including social deficits, communication, and interests, as well as prognosis, and intervention.

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

Purpose of the study:
The purpose of this study was to design a humanoid robot to use in intervention with children with ASD.

Method:
Participants:
The study conducted preliminary clinical trials using two graduate clinicians as intervention providers. Two typically developing children, a child with handicaps without ASD, and a child with ASD were used as intervention recipients.

Procedures/Assessment Instruments:
Troy, a humanoid was made to engage children. The robot was also made to be versatile, easy to use, and affordable. Preliminary clinical trials were completed with typical children to try out the possibility of using the robot with children. Interactions were based on a reciprocal turn-

taking sequence. Another preliminary clinical trial was completed using a child with handicaps without ASD. The interaction with Troy and the clinician also followed a reciprocal turn-taking sequence. Last, a child with ASD participated in a therapy session where the robot was used for 10 min of a 50 min session.

Results:
The results showed that while the robot was in the room, the children interacted more with the therapist. The preliminary clinical trial with the typical children demonstrated that it is possible to use a robot in an intervention setting. The children in this trial interacted with both the clinician and the robot. The child with handicaps without ASD also responded well to the robot and enjoyed interacting with him and gradually became less initimidated and more excited to see Troy. The child with ASD demonstrated positive interactions with the robot including positive affect.

Conclusions:
Results showed that Troy could be a useful tool to engage children and help them interact more during intervention.

Relevance to the current work:
This study relates to the current investigation because it focuses on the development of the same robot used in the intervention sessions that were studied in the current work. These positive results in the preliminary trials provided insight into how the children would react to the robot during intervention. This study also provides detailed information about the robot that was used in the current study.

Robins, B., Dickerson, P., Stribling, P., & Dautenhahn, K. (2004). Robot-mediated joint attention in children with autism. *Interaction Studies, 5*(2), 161-198.

Purpose of the study:
This study examined the potential robots have in an intervention or adacemic setting. The main behaviors analyzed were joint attention skills in children with ASD.

Method:
Participants:
The participants were taken from Bentfield Primary school in the UK. The three children involved were between five and 10 years of age and were diagnosed with ASD. The first child had acquired two or three words and was beginning to use the Picture Exchange Communication System. The second child had limited expressive and receptive language skills but could express some needs and understand simple directions. The third child had a learning disability paired with ASD and did not have any verbal expressive vocabulary. This child used signs to express simple needs.

Procedures/Assessment Instruments:
The children in this study participated in intervention sessions in the school with a humanoid robot, teacher, and an experimenter. The robot had two physical configurations: a female doll and a more traditional robot. The robot was able to dance to music and to rhymes. The

intervention sessions were set up in a way that allowed the children to have more freedom. The sessions lasted for 12 weeks. On average each child participated in nine sessions, lasting about three minutes each. The investigator in the room did not innitiate any interaction with the child but responded to initiation of interaction from the child.

Results:
Trascripts were made analyzing and recording vocalization and actions including conspicuous noticing, vocalizations and gaze, mutual orientation through gestures, and following others gaze. During analysis, researchers noticed that the first child payed close attention to a broken limb on the robot indicating a inner cognitive concern. The first child also produced a unique combination of vocalizations, gazes, and body postures indicating that the experimenter was the intended recipient of the vocalizations. Again, the first child established mutual gazes and proceded to gesture and change gaze towards a object of interest. The other two children were observed to follow another individual's gaze and pointing towards the robot.

Conclusions:
Robins, Dickerson, Stribling, and Dautenhahn indicated that robots can act as a social mediator (especially as a focus for joint attention) as these children communicate with others. Findings suggest that these children with ASD made more eye contact with and gave attention to the robot compared to an immobile toy truck. Robots can also help incourage children with ASD to imitate and take turns in games.

Relevance to the current work:
This study provided information that supports including robots into joint attention therapy for children with ASD. This study provided evidence that children with ASD are motivated by a robot to initiate joint attention with other individuals and to take turns in games.

Seibert, J. M., Hogan, A. E., & Munday, P. C. (1982). Assessing interactional competencies: The Early Social Communicaton Scales. *Infant Mental Health Journal, 3*, 244-245.

Purpose of the study:
The purpose of the study was to describe and support a theoretical instrument for assessing interactional abilities in children using a set of scales based on a cognitive developmental framework.

Summary:
To identify delays in social interaction, a model is needed to provide a guide to typical social skill development. An instrument is also needed to assess these abilities. The model needs to distinguish different social skills with their complexity and function. This study developed a model for children from birth to 30 months. The model also provided a social interaction assessment that placed the child on a continuum and offered insight to furthering their interactional development. The five developmental levels of the Early Social-Communication Scales (ESCS) are described. Instructions for administering and scoring the assessment are also prvodided.

Conclusions:

The ESCS has many limitations but is a good measure of strengths and weaknesses in social development as well as guide further intervention for social interactional skills.

Relevance to the current work:
This study relates to the current work because it provided a framework for the development of social skills. With the ESCS scales, the current study could identify weaknesses and strengths of the children participating as well as identify what they were ready to learn.

Silver, M., & Oakes, P. (2001). Evaluation of a new computer intervention to teach people with autism or asperger syndrome to recognize and predict emotions in others. *Autism, 5,* 229-316.

Purpose of the study:
The purpose of this study was to examine the outcome of a computer program on children with ASD and their skills in recognizing and predicting emotional responses in other individuals.

Method:
Participants:
Silver and Oakes used 22 children with ASD split into two groups ranging form 12 to 18 years of age. Each child was tested using the British Picture Vocabulary Scale and was above seven years in age equivalency.

Procedures/Assessment Instruments:
Before and after the study, the children were assessed using facial expression photographs, Happe's Strange Stories, and Emotion Recogniton Cartoons. Each child in one group used the computer program for a half hour, ten times within two weeks. The other group received normal classroom lessons. The computer program gave the child positive feedback if they chose correct answers. If the child answered incorrectly, they were prompted to try again. The program consisted of five sections all targeting emotion understanding through different situations.

Results:
Before intervention began, there was no different between the two groups. The children in the computer program group improved in all the sections from the first to the last session. The group who participatd in the computer program improved compared to the other group of children in all three assessments. The improvements made in the computer group correlated with the amount of time the program was used by each child.

Conclusions:
The authors conclude that the computer program had a positive effect on these children in the program itself and in the assessment procedures. The children's scores on the British Picture Vocabulary Scale were not related to change made in intervention. The authors conclude that the child's verbal abilities did not related to the amount of progress made during intervention.

Relevance to the current work:

This study relates to the current work because it studied the difference between involving technology in intervention with children with ASD compared to regular academic stimulation. These results provided evidence for including technology in intervention for children with ASD.

Taylor, B. A., Levin, L., & Jasper, S. (1999). Increasing play-related statements in children with autism toward their siblings: Effects of video modeling. *Journal of Developmental and Physical Disabilities, 11*, 253-264.

Purpose of the study:
The purpose of this study was to examine the impact of video models on commenting with children with ASD towards their siblings. Two experiments were conducted.

Method:
Participants:
In the first experiment, the participants included one male child and his sister. He was taken from an eductional program for children with ASD. This boy was six years old and his sister was eight. The boy with ASD was able to label nouns and verbs, imitiate, requests with three to four word sentences, and complete academic tasks. In the second experiment, the participant was a nine years old male and his brother was six years old. The boy with ASD spoke in seven to 10 word sentences, participated in acdemic activities, and conversed in simple conversations. Both participants rarely played with their sibling at the beginning of the study.

Procedures/Assessment Instruments:
The two boys' siblings were trained with a script as well as some role play exercises prior to the study, depending on their role in the experiment. In the first experiment, baseline was conducted as the first child with ASD and his sister. The children were instructed to play three activities. The sister said her script and allowed for her brother to respond. The play sessions were 5 min, one to three times a day. During intervention, the boy with ASD watched the videos three times and then an adult would go through the script with him and provide praise for providing comments. If he did not provide responses, he would continue to practice with the adult. Probe sessions were done everyday before the video modeling intervention and practice sessions to assess play comments. No reward was given during probe sessions. In the second experiment, baseline was conducted with three activitis and play related comments were recorded. Again sessions were 5 min, one to three times a day. In intervention sessions, the boy watched the first four comments on the video and then was provided the same stimuli by an adult. If the child provided comments, praise was given. The amount of video watched increased as the boy's ability increased. Probes were administered after the boy finished the forward chain procedure and achieved acquisition criteria.

Results:
In the first experiment, during baseline the child did not say any scripted or unscripted comments. After the video modeling intervention, the boy was able to learn almost all of his scripted comments. Within nine probe sessions, this boy was able to meet criterion for all three activities. There were no unscripted comments made during baseline or video modeling intervention. In the second experiment the number of comments made during baseline was

significantly below the amount of play comments made, scripted and unscripted, during probe sessions.

Conclusions:
For the first experiment, the results indicated that video modeling intervention led to improved scripted play comments but not unscripted comments. Results for the second experiment indicated that forward chaining video modeling increased play comments with the child with ASD.

Relevance to the current work:
This study relates to the current study as they both explore children with ASD and their response to technology used in intervention sessions. Both studies looked at social engagement behaviors and support the idea of putting technology into intervention sessions.

Tomasello, M., & Farrar, F. J. (1986). Joint attention and early language. *Child Development, 57*, 1454-1463.

Purpose of the study:
The purpose of this study was to examine joint attention skills and relate these skills to the more general acquisition of language behaviors.

Method:
Participants:
In the first study, 24 children were used. These children were all white, middle-class, and between 12 and 18 months old. Each child had also began to produce language. In the second study, 10 children were used age 17 months. These children were middle-class and speaking several words.

Procedures/Assessment Instruments:
In the first study, the children were videotaped at ages 15 and 21 months while interacting with their mothers in their home. Each mother was given a set of toys and directed to play normally. Each video was coded for joint attention and then transcribed and coded for language behaviors. Other language measures were taken from the child such as MLU, total number of words and object-labels per minute. The mothers were also evaluated for MLU and the amount of utterances such as comments, questions, and directives. The number of conversations were also noted along with the number of turns the child made. All these behaviors were measured inside and outside of joint attention episodes. These videos were coded again for more behaviors including the mother’s attention to an object in reference to the child’s attention, gestures, and the child’s visual focus. The child’s language was also assessed using a modified version of the Bates interview as well as vocabulary size. In the second study, children were taught new words by an adult in a quiet room. The child was tested and trained in four training sessions. Each child was assigned four unfamiliar objects. Two objects were assigned to the follow-in, or taught when the child was initially engaged in the object and was given a sentence with the object’s name stressed. The other two objects were taught in a direct condition or taught when the child was not initially engaged on the object. The children were tested on the objects names before training, during each training session, and two weeks following training.

Results:
Results showed that the mother and child interacted inside joint attention epsiodes two-thirds of the time they were observed. The children produced more utterances, words, and words referring to objects per minute inside joint attention episodes as compared to outside joint attention episodes. The child's number of turns taken was also higher inside joint attention episodes. Each of these behaviors had increased at 21 months compared to 15 months levels. Joint attention episodes, when the mother referenced objects that the child was already attending to, were positively correlated to the child's vocabulary at 21 months. On the other hand, directing the child's attention to other objects was negatively correlated to vocabulary at 21 months. The results of the second study indicate that the words that were more easily learned were those that the children's were already attending to and did not have to be directed towards.

Conclusions:
The authors concluded from the first study that it is possible that joint attention provides a scaffold for early language interaction. On the other hand, it is possible that the linguistic dyad interaction provides a environment to establish and maintain joint attention. Combining the studies, the authors conclude that joint attention is important in early language learning because it provides non-linguistic scaffolding, and extended joint attention episodes make it possible for children to learn new words in just a few exposures.

Relevance to the current work:
These studies relate to the current work because their conclusions emphasize the importance of joint attention in early language learning.

Van Hecke, A. V., Mundy, P. C., Acra, C. F., Block, J. J., Delgado, C. E. F., Parlade, M. V., Meyer, J. A., Neal, A. R., Pomares, Y. B. (2007). Infant joint attention, temperament, and social competence in preschool children. *Child Development, 78*(1), 53-69.

Purpose of the study:
This study examined typically developing children's joint attenton skills and how these skills relate to social outcomes.

Method:
Participants:
This study used 52 typically developing children beginning at 12 months of age. These children were taken from a sample of 76 infants who were in a social development longitudinal study. All the children had a score of seven or greater on the 5-min APGAR, no major medical or developmental problems, and a score of 75 or greater on the Bayley Mental Developmental Index.

Procedures/Assessment Instruments:
The children were assessed for language at nine months, joint attention at 12 months, temperament at 15 months, cognitive/language data at 24 months, and social-emotional outcomes at 30 months. The children were assessed using the Early Social Communication

Scales at 12 months to look at their joint attention. Temperament was assessed using the Toddler Behavior Assessment Questionnaire-Revised. Cognition was assessed using the Bayley Scales of Infant Development-Second Edition. The last assessment for social-emotional outcomes was the Infant-Toddler Social and Emotional assessment questionnaire.

Results:
The children who were using eye contact and pointing or showing to share experiences, or responding to joint attention such as following gaze at 12 months, were reported to be more social at 30 months.

Conclusions:
It was apparent that joint attention was important for several aspects of development including language, cognitive, social, and behavioral skills.

Relevance to the current work:
This study indicated that joint attention is an important factor in development of several essential behaviors including language, cognitive, social, and behavioral skills.

Volker, M. A., & Lopata, C. (2008). Autism: A review of biological bases, assessment, and intervention. *School Psychology Quarterly, 23*(2), 258-270. doi:10.1037/1045-3830.23.2.258

Purpose of the study:
The purpose of this article was to review research on ASD in the areas of genetics, neurological features, assessment, and intervention.

Summary:
The prevalence for ASD is about 10-16/10,000 people. ASD is usually associated with other problems including intellectual disabilities, seizures, and genetic syndromes. There is a strong genetic link to ASD. ASD is also neurological, but the neurological characteristics vary greatly among individuals. In assessing children with ASD, most individuals will be identified before school age, but some will also be diagnosed at school age. The assessment includes medical, genetic, audiological, psychological, speech and language, motor, and educational aspects. Due to the heterogeneity of the disorder, intervention is different for each individual. Therapy can take the form of a strucutured or naturalistic behavioral approach, cognitive behavioral approach, or pharmacological approach.

Conclusions:
Volker and Lapata concluded that knowledge of ASD has grown substantially in recent years. Diagnosing ASD has improved with new instruments. Treating ASD has improved with new behavioral and pharmocological interventions.

Relevance to the current work:
This work provides background for the current study including information about assessment and intervention for ASD.

Wainer, J., Ferrari, E., Dautenhahn, K., & Robins, B. (2010). The effectiveness of using a robotics class to foster collaboration among groups of children with autism in an exploratory study. *Personal and Ubiguitous Computing, 14*(5), 443-455. doi:10.1007/s00779-009-0266

Purpose of the study:
The purpose of this study was to examine children with ASD in a robotic programming class and consider the impact on collaboration skills.

Method:
Participants:
Children at the St. Nicholas Academy for Autism Project who were enrolled in a weekly class for programming robots were studied. There were seven male children who attended the class more than 60% of the time, and these children were examined. These children all were diagnosed with high functioning ASD.

Procedures/Assessment Instruments:
The children who participated in this study were divided into three groups and were given a Lego NXT robot. These children programmed the Lego robots in a class that took place once a week for several months for a total of 12 lessons. They used the program NXT-G. In each class, the experimenter would teach a new robot lesson for the first 15 min. After the lesson, the children would play and show what they had learned for the remaining 45 min. The experimenters studied the amount of collaborative play among the children across 11 of these 12 sessions. To analyze these behaviors, interviews with the parents, written questionnaires for both the children and the parents, and video analysis were used. In the video analysis, group proxemics, shared gaze, robot-related speech, pointing behavior, and shared positive affect were observed.

Results:
The results from the questionnaires conclude that both the parents and the children reported that the classes were enjoyable. From the video, the children spent more time close in proxemity and sharing gaze during classes. These children also spoke more often about the robot during their last classes compared to their first and during the more enjoyable classes compared to the ones that were not as enjoyable. The children also demonstrated more pointing and positive affect during the more enjoyable classes. Parents reported that they thought the robot classes were helping their children be more socialable, confident in approaching and helping others, participate in conversations about normal topics, and to take turns.

Conclusions:
The parents' responses in the questionnaire were reliable in indicating that their children were enjoying the classes. From the videos, the authors concluded that the amount of collaborative behaviors correlated with amount of enjoyment the children were experiencing. The authors also concluded that the children found it enjoyable to continue interacting with others after the robot classes ended.

Relevance to the current work:

This study relates to the current work because it provided reliable data that children with ASD enjoy working with robots.

Wetherby, A. M., Woods, J., Allen, L., Cleary, J. Dickinson, H., & Lord, C. (2004). Early indicators of autism spectrum disorder in the second year of life. *Journal of Autism and Developmental Disorders, 34*(5), 473-493.

Purpose of the study:
The purpose of this study was to identify red flags to accurately identifying differences in children with ASD, developmental delays, and typical development through analyzing videotapes of children in these categories. Wetherby et al. also explored different assessment materials in accurately diagnosing ASD.

Method:
Participants:
In this study, 18 children were studied from three different groups including ASD, developmental delays without ASD, and typically development. All participants were under the age of two. All the children participating in this study also participated in another longitudinal study.

Procedures/Assessment Instruments:
Before the study began, each family completed the CSBS DP Infant-Toddler Checklist. A sample was then taken of each child to observe different behaviors. During the sample, the child was presented with various prompts for spontaneous behavior such as joint attention and understanding their own name. Each sample was videotaped and scored using the CSBS DP and the Systematic Observation of Red Flags (SORF). The SORF looks at behaviors in 29 items under the categories of reciprocal social interaction, unconventional gestures, unconventional sounds and words, repetitive behaviors and restricted interest, and emotional regulation.

Results:
After comparing the Infant-Toddler Checklist with developmental outcomes the researchers found that the Checklist had a sensitivity of 94.4% when the group with ASD and the typically developing group were included. Sensitivity was 88.9% when the group with ASD and developmental delays were included. Parents of children with ASD expressed more concern on the checklist than parents of typically developing children but did not differ from parents of children who were developmentally delayed. Parents of children with ASD did express concern more often in multiple areas compared to parents of children with developmental delays. Looking at the SORF items, children with ASD differed from all the other children in (a) lack of appropriate gaze; (b) lack of positive expressions with gaze; (c) lack of sharing enjoyment; (d) lack of response to name; (e) lack of coordination of gaze, facial expression, gesture, and sound; (f) lack of showing; (g) unusual prosody; (h) repetitive movements or posturing of body parts; and (i) repetitive movements with objects.

Conclusions:
Wetherby et al. found that the Infant-Toddler Checklist was a good tool for identifying children with ASD as having communication impairments. After analyzing the videotapes for red flags,

nine behaviors were found to distinguish children with ASD from a child with developmental delays or a typical child. These nine red flags include (a) lack of appropriate gaze; (b) lack of joyful expressions with gaze; (c) lack of sharing interest; (d) lack of response to name; (e) lack of coordination of gaze, facial expression, gesture, and sound; (f) lack of showing; (g) unusual prosody; (h) repetitive movements or posturing of body; and (i) repetitive movement with objects.

Relevance to the current work:
Wetherby et al. provided insight about the characteristics that identify and characterize ASD. Included among the red flags are lack of appropriate gaze, joyful expression with gaze, responding behaviors, and other joint attention behaviors. The current study examined these exemplars of engagement and attempted to use robotics in therapy to improve engagement in children with ASD.

Wimpory, D. C., Hobson, R. P., Williams, J. M. G., & Nash, S. (2000). Are infants with autism socially engaged? A study of recent retrospective parental reports. *Journal of Autism and Developmental Disorders, 30*(6), 525-536.

Purpose of the study:
The purpose of this study was to compare social engagement behaviors in children with ASD and children with developmental delays.

Method:
Participants:
Parents of 10 children with ASD and 10 children with developmental delays without ASD were examined. All of the children were matched according to age and developmental level.

Procedures/Assessment Instruments:
Parents of the children with ASD and typically developing children were interviewed using the Detection of Autism by Infant Sociability Interview. This interview highlights 19 different aspects of social engagement. The interview took place before diagnostic procedures were performed. The interview was conducted while the children were young, focusing on the first two years of their life.

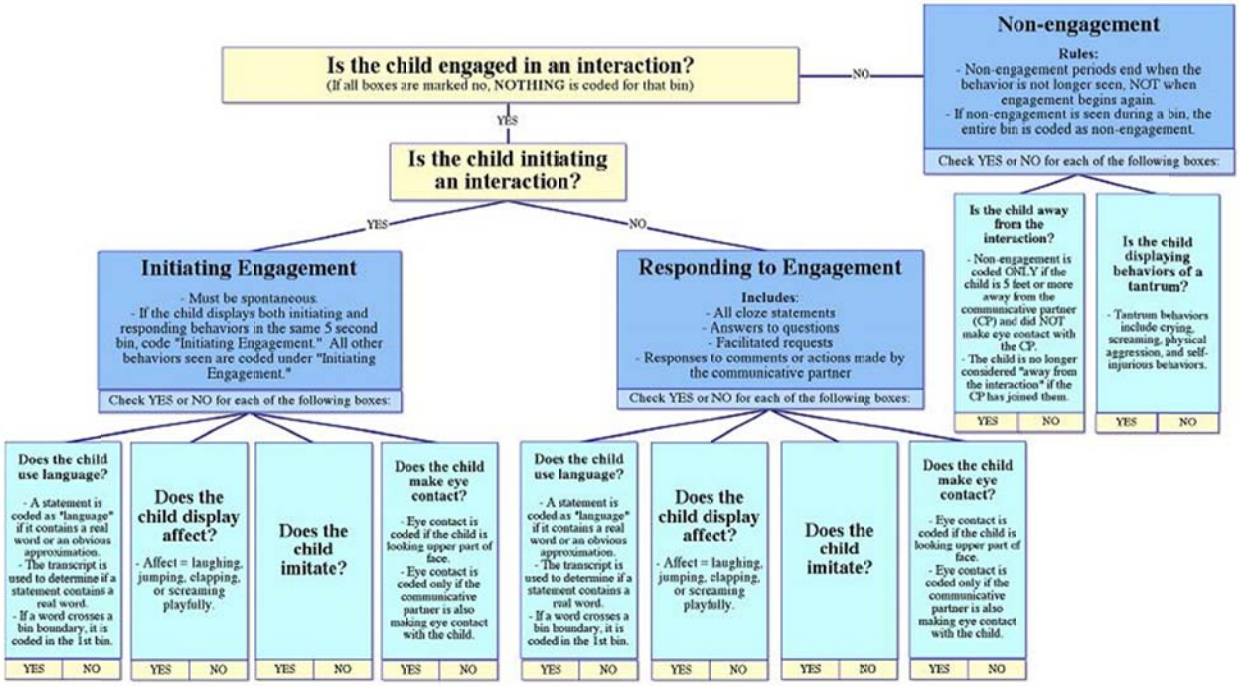
Results:
The results of the interviews indicated that the children with ASD differ developmentally in social engagement on 16 different items compared to age matched and developmentally matched peers.

Conclusions:
Results indicated that children with ASD differ from children with developmental delays in person-to-person and person-to-object social engagement.

Relevance to the current work:
Wimpory et al. concluded that children with ASD have deficits in social engagement, which supports the idea of targeting social engagement in intervention.

Appendix B

Coding system for initiating engagement, responding to engagement and non-engagement



Additional coding guidelines (Hansen, 2011):

- Code *non-engagement* when the child is out of the therapy room during intervention.
- Code the entire 5-sec interval as *non-engagement* when the child demonstrates non-engagement behaviors at any time during the interval.
- Code non-engagement when the child is not at the interaction, even if they're returning, unless they are making eye contact.
- Once the child is within five feet of interaction, it is no longer coded as non-engagement.
- When non-engagement behavior ends, the non-engagement period has ended, not when engagement behaviors are seen.
- If initiating engagement behaviors are seen along with responding to engagement behaviors in the same 5-sec interval, put everything in initiating engagement category.

- Initiating engagement is coded when the child spontaneously demonstrates behavior, not in response to anyone else.
- Responding to engagement is coded when the child is responding to any behavior coming from the robot or adult.
- Eye contact is coded when the child is looking at the upper part of the face and the partner is looking back.
- Language is coded when the child uses language or an obvious approximation.
- When a word spans across two intervals, only the first interval is coded for language.
- Affect is coded when the child demonstrated behaviors such as laughing, jumping, clapping, or playful screaming.