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ABSTRACT

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This study focuses on the use of a humanoid robot to facilitate the initiation of social engagement behaviors in two children with Autism Spectrum Disorder (ASD). Approximately 10 minutes of a 50-minute treatment session were devoted to interaction using a humanoid robot, Troy, to facilitate interactions with a graduate clinician or caretaker. These interactions were recorded, analyzed, and coded in 5 s intervals. This study focused specifically on the children's initiations of social engagement behaviors. Results suggested that the robot had potential to facilitate social engagement between the children and the adults.

Keywords: autism, robotics, joint attention

ACKNOWLEDGMENTS

I would like to thank Dr. Brinton, Dr. Fujiki, and Dr. Colton for all their help with this project. Thanks to my research partner, Katherine Lowe, for her help in coding all of the sessions. I could not have finished this project without her help. I would also like to thank my parents for their encouragement and support throughout my entire college education. A special thanks to my husband, Kyle, who supported me with patience and love through my graduate education.

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DESCRIPTION OF STRUCTURE AND CONTENT

This thesis is presented in a hybrid format where current journal publication formatting is blended with traditional thesis requirements. The introductory pages are therefore a reflection of the most up to date university requirements while the thesis report reflects current length and style standards for research published in peer reviewed journals for communication disorders. Appendix A is composed of an annotated bibliography. Appendix B includes an example of an interaction between the child and Troy. Appendix C includes a description of the coding procedures.

Introduction

Autism Spectrum Disorder (ASD) includes a range of disorders that appear to be increasing in prevalence (Prelock & Contompasis, 2006; Wing & Potter, 2009). Considerable study has been devoted to the description of the behavioral manifestations of ASD. The *Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition* (1994) defines ASD as a disorder involving impairments of social interaction, communication, and "restricted repetitive and stereotyped patterns of behavior" (p. 71). The difficulties that children with ASD demonstrate in language and communication are well documented (Campolo et al., 2008). Some children with ASD do not develop verbal language, and others demonstrate delayed or limited development resulting in a "lack of communicative competence" (Bruinsma, Koegel, & Koegel, 2004, p. 173; see also Conti-Ramsden, Simkin, & Botting, 2006; Rapin, 1991; Scattone, 2007; Watson & Flippin, 2008; Westby, 2010; Wing & Potter, 2009).

Recent research has suggested that difficulty developing joint attention (JA) behaviors may explain some of the difficulty children with ASD experience in language acquisition and use. JA, or "the integration of information about self-experience of an object or event with information about how others experience the same object or event" (Westby, 2010, p. 137), is critical to social engagement with others.

Joint Attention

Mundy, Sigman, Ungerer, and Sherman (1986) defined JA as "the use of procedures (e.g. showing a toy) to co-ordinate attention between interactive social partners with respect to objects or events in order to share an awareness of the objects or events" (p. 657). Bruinsma et al. (2004) noted that JA includes a group of behaviors that "share a common goal of communicating with another person about a third entity in a nonverbal way" (p. 169). Westby (2010) described three categories of JA: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). Westby (2010) indicated that responding to JA occurs when "the infant follows the direction of gaze, head turn, and or point gesture of another person" (p. 137), while initiating JA involves "seeking interaction with another simply for the sake of sharing an experience" (p. 137). The development of all types of JA, but especially IJA, is foundational to social engagement in typical children (Bruisma et al., 2004; Westby, 2010). The development of JA behaviors is related to the emergence of intentional communication, which is, in turn, critical to the development of language (Bruinsma et al., 2004).

Joint Attention and Social Engagement in Children with ASD

As Westby (2010) noted, a key aspect of ASD is "the child's inability to enter into joint attention and affective contact with other people" (p. 156). Limited JA and a resulting lack of social engagement are often major diagnostic indicators of ASD. Children with ASD may experience more difficulty establishing JA than do children with other disabilities such as intellectual disability (Mundy et al.,1986; Prelock & Contompasis, 2006). Blackwell (2001) identified interactional deficits including difficulty with eye contact, pretend play, and joint attention in children with ASD as young as 18 months of age. Rapin (1991) reported that children with ASD often lack the ability to respond to bids for JA, and Mundy, Sigman, and Kasari (1994) noted that although "the majority of children with autism [will] eventually develop [both] RJA and IBR," (p. 156) they will continue to exhibit deficits in IJA.

Intervention programs designed for children with ASD frequently target all types of JA in an attempt to increase social engagement. It has often been a challenge, however, to draw children with ASD into social interactions with others (Prelock & Ducker, 2006). This has particularly been the case with children who demonstrate more severe deficits. Recently, a number of researchers have investigated the possibility of using robots to engage children with ASD in interaction.

The Use of Robotics to Establish Social Engagement

Recent research has suggested that robots might be used as a tool to engage children with ASD in reciprocal interaction (Goodrich, Colton, Brinton, & Fujiki, 2011; Robins, Dickerson, Stribling, & Dautenhahn, 2004). There is evidence that children with ASD find robots particularly compelling. Scasselatti (n.d.) found that typically developing children engaged with a robot initially but gradually lost interest. Likewise, Tanaka, Cicourel, and Movellan (2007) also reported that typically developing children in a preschool setting lost interest in a robot when it behaved in a predictable manner. In contrast, Scasselatti (n.d.) reported that children with ASD showed consistent motivation and interest when a robot was used in therapy sessions. Scasselatti (n.d.) also reported that children with ASD showed interest in the robot whether or not it was initiating or responding to the child. JA skills were previously absent in these children; but, when therapy included an interaction with a robot these children began to display these JA skills with the robot.

Blomgren and Tenggren (n.d.) suggested that children with ASD might find interacting with a robot less intimidating because a robot is predictable and has a limited amount of fixed communication (see also Goldsmith & LeBlanc, 2004). Scassellati (n.d.) suggested that because researchers can control the specific behaviors a robot manifests, particular social skills might be demonstrated and identically replicated for individuals with ASD.

Robins et al. (2004) conducted a study lasting 12 weeks that specifically focused on encouraging turn-taking, imitation, and JA skills of four children with ASD. They analyzed the initiations and responses of these children with a robot and another human. The results from this study showed that the children demonstrated JA skills where the robot was the common medium between the child and the adult (Robins et al., 2004); however, generalization of these skills to human interaction was difficult to establish. Robins et al. (2004) emphasized the idea that interactions with a robot should not replace interactions with another human because interactions with humans can help provide meaning that otherwise could not be part of the interaction.

In 2010, a research team at Brigham Young University reported preliminary results of a pilot study investigating the efficacy of including a robot in a 15-week treatment program with two children with ASD (Acerson, 2011; Goodrich et al., 2011; Hansen, 2011). Intervention with the robot was considered low dose because each child was exposed to the robot for only 10 min of a 50-min treatment session twice a week. Pre- and post- treatment measures of social engagement conducted without the robot suggested that one child showed a dramatic increase in social engagement behaviors and the second child showed modest gains. The social engagement behaviors the two children produced during the intervention sessions with the robot were not analyzed, however. The purpose of the current study is to describe each child's initiation of social engagement behaviors with a caregiver or clinician within the treatment segments when the robot was present.

Method

Participants

The participants in this study included two males with ASD who were previously receiving services at the BYU Speech and Language Clinic. The participants exhibited moderate to severe deficits in social communication. Neither child had demonstrated marked improvement in social engagement behaviors over the previous several months despite receiving intervention services. The participants' names were changed for the purpose of this paper to Alex and Chris. This was done in order to protect the participants' privacy and to remain consistent with previous reports (Acerson, 2011; Hansen, 2011).

Alex. Alex was 3;5 at the time of the study. At the age of 24 months, Alex was evaluated by a child psychologist who identified him with PDD-NOS using the Autism Diagnostic Observation Schedule (Lord, Rutter, DiLavore, & Risi, 2001). Additional deficits were noted including borderline IQ, language delay, sensory problems, and gross motor delays (e.g. sat up at 6 months and walked at 27 months). The following information was obtained from a case history completed by his mother when Alex was 30 months old. Additional information was taken from reports of Alex's psychological and medical examination at the age of 2;6.

Speech and language development. Alex's first words were *dad* and *tub* at the age of 20 months; however, at the time of the study, he no longer used either of these words. At the age of 30 months, Alex had no verbal language. Alex communicated his desires by taking the communication partner by the hand to the desired item/location. In addition, Alex's receptive language was quite limited, and he only followed some simple commands (e.g. *let's go*). Alex did not respond to other commands such as *stop, wait, eat,* and *sleep.*

Social development. Alex's mother expressed concern about Alex's lack of attention to faces. She reported that he had a limited attention span for activities, whether self-directed or adult-directed. His only regular playmates consisted of his older siblings; yet, he enjoyed these interactions. Play with his older siblings typically consisted of sensory motor activities (e.g. running, jumping, and swinging). Alex's psychologist noted that Alex seemed to have a social interest in people, but that he had a difficult time engaging in social play and rarely initiated or responded to bids for JA. Alex's mother reported that Alex would not look at a person if he/she were pointing to an object although he would occasionally look at the object.

Education history. Alex received early intervention services at the age of 10 months. These services were provided once a month and included speech, language, and physical therapy. The professionals involved in this intervention used a consultation intervention model and integrated parent education into Alex's treatment plan.

Alex began attending his school district's preschool for children with special needs and typically developing children when he was 3;2. Alex initially had difficulty separating from his mother as well as adjusting to the preschool routines. Alex did not initiate social interactions with his peers, but his teacher reported that Alex began observing his peers' social interactions with each other. He would often play alone near his peers without engaging in the interactions with them. Alex exhibited limited social communication skills with his teachers; his communicative bids were limited to non-verbal requests for a drink and a snack. While attending the preschool, Alex received speech and language services from the school SLP.

History of speech and language services. A speech and language assessment was performed in the BYU Speech-Language Pathology Clinic when Alex was 3;1. The *Preschool Language Scale-4th Edition (PLS-4)* (Zimmerman, Steiner, & Pond, 2001) was administered and the *Westby Playscale* (Westby, 1980) was used to guide observations of Alex's play, social engagement, and communication. On the *PLS-4*, Alex scored 2.5 standard deviations below the mean in both auditory comprehension and expressive communication, placing him in the first percentile. In May 2009, at the age of 33 months, Alex began treatment at the BYU Speech and Language Clinic for speech, language, and social function delays. (For additional information, see Appendix D.)

On January 14, 2010 when Alex was 3;5, the *Westby Playscale* was re-administered by a graduate student involved with this study. Results indicated Alex made little progress in developmental play skills as he continued to play at the Pre-symbolic Level II.

Informal observation and language samples revealed Alex's ability to follow simple commands, such as *wait*, *hold hand*, and *stop* with verbal and tactile cues; however, he did not follow verbal commands without tactile cues. Alex named the letters: *E, Z, X, O,* and *L* with the aid of a visual prompt, but he did not produce any words. He participated in some activities with a clinician (i.e., rolling a ball, playing with cars, playing with blocks, etc.), but he did not establish eye contact, imitate, share affect, or establish JA.

Alex demonstrated difficulty engaging in activities during therapy. Instead, Alex tended to sit in a corner and rock or spin toys and persisted in these behaviors as long as he was allowed to do so. The clinician used frequent prompting and sensory stimulation to engage Alex. Once Alex was engaged in a task, he typically stayed with the task for about 1 min before becoming disinterested. Alex's mother attended every session, and a key goal of treatment was to assist her to interact with Alex in ways that were most engaging for him.

Chris. Chris was 7;11 years old when this study took place. He had previously been followed by a child psychologist and identified with attention deficit hyperactive disorder (ADHD) at 36 months and with ASD at 48 months.

Birth, medical and developmental history. The following information was obtained from Chris's case history completed by his mother when Chris was 48 months old. She reported that Chris had developed motor milestones within normal limits (sat up at six months, crawled at eight months, and walked at nine months), but had shown marked delays in other developmental domains. At the time of the study, Chris had passed hearing screening measures and was taking medications for ADHD.

Speech and language development. Chris's mother reported he spoke his first words (i.e. *ball, mama,* and *uh-oh)* at 12 months; however, Chris's mother also reported he spoke only in one-word utterances at the age of 48 months. The *PLS-4* was administered in when Chris was 5:0 years old. Chris scored three standard deviations below the mean in both auditory comprehension and expressive communication. At the time of the study, Chris used a few two to four word phrases to communicate (e.g. "I want juice, please") with prompting. Chris used the word *please* independently to request items; however, he rarely used eye contact with these requests. A majority of the time, Chris would not share interest in an object but would use the communication partner as an instrument (e.g. getting a desired item for him).

Education history. Chris began receiving intervention services when he was 5;0. Intervention goals focused on following one-step directions, imitating simple actions, saying his name correctly, answering yes/no questions about himself, and making requests. At the time of the study, Chris attended a self-contained special education classroom at a local public elementary school where he also received speech and language services. Some of his IEP goals consisted of learning to write his name, address, and phone number, completing simple addition problems, reading sight words, reading comprehension, fine motor skills, verbally expressing wants and needs, producing CVC target words, and participating in classroom activities with fewer than five prompts.

History of speech and language services. In September 2008, at the age of 6;6, Chris began treatment at the BYU Speech and Language Clinic for speech, language, and social delays. Chris's goals included the following: (a) increasing the frequency of eye contact; (b) participating in reciprocal play; and (c) increasing expressive language. Prior to the study, Chris demonstrated repetitive behaviors, acting out behaviors, and difficulty staying engaged during an activity in the therapy session. Chris demonstrated restricted interest in toy LEGOS® and LEGO®men. He often brought these toys to therapy from home. During the sessions, Chris would walk around the room talking to his LEGO®man while ignoring the clinician's attempts to get him engaged in another activity. Chris required continual prompting from the clinician; he was easily distracted, and his episodes of engagement were rare and brief. When Chris became overstimulated, he would bounce and flap his arms. The clinician introduced large bean bag chairs for Chris to sit on to help him regulate his behavior.

The Robot: Troy

The humanoid robot, referred to as Troy, was created by graduate students from the Brigham Young University Department of Mechanical Engineering. Troy was an upper-body robot that was designed with human attributes, including a base, trunk, 2 arms, neck, and head (Ricks, 2010). The humanoid was designed to be the approximate size of the average 3-4 year old. As such, he had a 9x11 inch (22.9x27.9 cm) base and was approximately 25 inches (63.5 cm) tall (from the bottom of the base to the top of the head) with arms approximately 12 inches

(30.5 cm) in length (see Figure 1). He was programmed with the ability to produce human-like movements of the arms and neck, basic facial expressions, and verbal songs and phrases.

Figure 1. Pictures of Troy from the front, side, and back view. 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.

Troy's neck, shoulders, and arms were created using actuated RC servo motors. Troy's arms contained four degrees of freedom for movement to allow him to participate in the JA interactions (Ricks, 2010). These movements included: one for shoulder flexion/extension, one for shoulder abduction/adduction, one for humeral rotation, and one for elbow flexion/extension (Ricks, 2010). Simple actions included pushing a toy car, tapping a tambourine, waving hello, etc. (Ricks, 2010). Troy's neck was designed to move anteriorly, posteriorly, and laterally.

Troy also contained a speaker that was connected to a laptop through a USB port. Previously recorded sounds and phrases stored in the computer were played through Troy's speaker, giving Troy the ability to produce the phrase or sound of the clinician's choosing. A student from the Music Dance Theatre Program at Brigham Young University recorded phrases such as *Hi Chris* and *Uh-oh* and songs such as *Popcorn Popping on the Apricot Tree* and *Three Little Monkeys Swinging in the Tree*.

Two video cameras were used to record the interactions between the child, graduate clinician, assisting graduate clinician, parent (when available), and Troy. The first of these cameras was a Network Camera™. This camera was mounted on the wall opposite Troy. Thus, the camera was focused on the front of Troy and the back of the child. The second camera was a Canon™ digital, handheld. This camera was student operated and was located behind Troy (opposite of the Network Camera™'s location). Thus, the view of this camera was focused on the front of the child (particularly the child's face).

Procedures

Each participant was seen for language intervention for two 50-min sessions a week. A 10-15 min interaction with Troy was included in these regular treatment sessions. The robot segments were scheduled during a random time in the session (i.e. beginning, middle, or end). The robot was introduced to the child, and the clinician then attempted to engage the child in joint games and activities involving the robot, the clinician, the child, and a parent when available (Acerson, 2011; Hansen, 2011).

Forty minutes of treatment without Troy. Therapy was patterned after a "family centered, naturalistic, interactive, and child-centered therapy model" (Acerson, 2011). Goals included: improving JA skills (such as frequency of eye contact, initiating activities, and turn-taking), improving expressive language by increasing appropriateness and length of responses, and improving play skills (through symbolic play) (Acerson, 2011; Hansen, 2011). Therapy included a picture schedule indicating the activities for the session. These activities included a table activity (e.g. reading a book), motor activity (e.g. hopping on carpet squares or running around the room), play activity (i.e. symbolic play with various toys), and a snack.

Ten minutes of treatment with Troy. Treatment with Troy consisted of a triadic interaction (i.e. Chris) or a quadratic interaction (i.e. Alex) focusing on JA and social engagement. Interactions included Troy, the graduate clinician, and the child. Alex's mother participated in his treatment sessions. During interactions, an assisting graduate clinician sat behind the child and provided hand-over-hand support as well as models of appropriate responses. This segment of therapy began with an exchange of greetings (e.g. "Hi Alex!" "Hi Troy!" etc.) accompanied by waving. The second segment included a group activity consisting of an exchange of turns manipulating a toy (e.g. bowling ball, truck, or tambourine). The third segment included singing and performing actions as a group; songs included *Popcorn Popping on the Apricot Tree* and *Three Little Monkeys Swinging in the Tree* (Acerson, 2011; Hansen, 2011). The last segment included a farewell to Troy and the assisting graduate clinician by saying *bye* and waving. It is important to note that occasionally an additional segment was included in Chris's treatment which included facial expression imitation games. Interactions with Troy and the clinicians were structured to highlight the sharing of affect and that contrasting affect was used. An example of an exchange during these interactions is described in Appendix A.

Data analysis. Each of the 10-15 min interactions using the robot was broken up into 5 s intervals. These segments were analyzed and instances where the children were socially engaged with another person (clinician or parent) were identified. The analysis system used in this study was originally patterned after the work of Kasari et al. (2006) but adapted for use with older children (Acerson, 2011; Hansen, 2011). The system was designed to identify and describe behaviors the children produced when they were socially engaged with another person. Two investigators were trained in the analysis system and independently coded 10% of the sessions for each child. Interjudge agreement was established at 93% for each of the engagement categories (i.e. initiating engagement, responding engagement, and the four categories under each including *language, affect, imitation,* and *eye contact*). The investigators then coded the remaining sessions independently.

Two basic categories of engagement behavior were identified, *Initiating Engagement* and *Responding to Engagement. Initiating Engagement* behaviors were spontaneous bids for social engagement produced by the children. That is, they were not produced in response to an initiation by another. The current study focused only on instances when the children produced behaviors that initiated engagement with a communication partner.

Four specific initiating engagement behaviors were identified: *language, affect, imitation,* and *eye contact*. *Language* behaviors consisted of real words or obvious approximations of words. *Affect* was coded when the child demonstrated one or more of the following behaviors: laughing, jumping, clapping, playful screaming. Instances of *imitation* were coded when the child imitated or repeated an action displayed by the communication partner. *Eye contact* was identified when the child looked at the upper half of the communication partner's face while the communication partner was looking back. These behaviors sometimes co-occurred within a time interval. For example, if the child displayed affect while making eye contact with the communication partner, both *affect* and *eye contact* were coded for that particular 5 s segment. In addition, if the child demonstrated a behavior coded as *Initiating Engagement* and then subsequently responded to his partner's response, both behaviors were coded as *Initiating Engagement.* For example, if the child initiated eye contact but then imitated the clinician during a 5 s segment, both behaviors were coded as *Initiating Engagement* behaviors, *eye contact* and *imitation*. Therefore, an *imitating* behavior could be coded under *Initiating Engagement*. (For additional information on coding procedures, see Appendix B.)

In addition to coding the four engagement behaviors directed toward the adults in the session, engagement behaviors directed only toward the robot were also coded. These instances were coded under the category, *robot only*. If the child directed engagement behaviors toward an adult as well as toward the robot within a 5 s segment (e.g., the child imitated the robot while looking at the clinician), these instances were coded in the robot only category.

Results

The current study is part of a larger project. Within the larger project, pre- and post-intervention assessments for each child were conducted in four different contexts. These contexts included unstructured interaction between each child and his parent, interaction with an unfamiliar adult, interaction with the child's clinician, and interaction in a triad with clinicians. Instances of social engagement were identified in each of these contexts. Results of these assessments have been reported previously (Acerson, 2011; Hansen, 2011). The current study describes the participants' initiations of social engagement behaviors with a caregiver or clinician within the treatment segments using the robot. Within each 5 s interval, the child's initiations were identified according to the partner with whom the child engaged: the adult (parent or clinician), robot only, and both the adult and the robot.

Alex's Performance

Social engagement with the caregiver and/or clinician. Figure 2 presents the total number of instances in each session in which Alex initiated social engagement with his mother or clinicians. It is important to note that Alex's language consisted of approximations of words (e.g. "*ŋ*" for "sing" and "*ək*" for "truck"). The number of social engagement behaviors generally increased across the sessions with the exception of sessions 9 and 10. During session 9, Alex held on to a sippy cup throughout the entire session and periodically drank from it thus making it more difficult for him to interact. In addition, the session ended a little early because Alex needed to go to the bathroom. It is important to note that during session 10, Troy was not working so the clinicians spent periods of time trying to fix the situation, thus Alex was allowed to just sit and look at Troy. In addition, the assisting clinician stood up by the computer to try to have Troy do a few actions, so she was not sitting behind Alex helping him with hand over hand support.

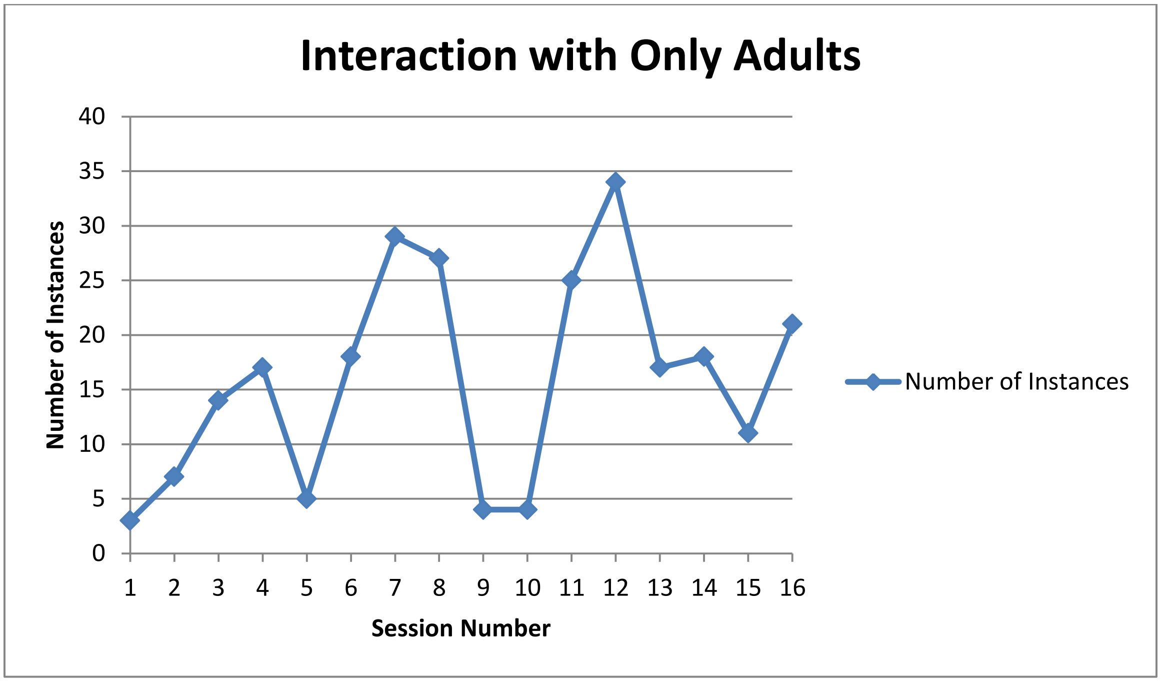

Figure 2. The total number of instances in each session in which Alex initiated social engagement with an adult.

Figure 3 presents the instances in each session in which Alex initiated social engagement using each of the four categories, *language*, *affect*, *imitation*, and *eye contact*. There was considerable variation in these behaviors across sessions. *Eye contact* increased most dramatically with the exception of sessions 9 and 10. Again, Alex was preoccupied with his sippy cup during the entirety of session 9, and there were technical difficulties with Troy throughout session 10. *Language*, *affect*, and *imitation* fluctuated greatly from session to session. It should be noted that these behaviors varied according to the activities that the clinicians introduced and Alex's play preferences on a given day.

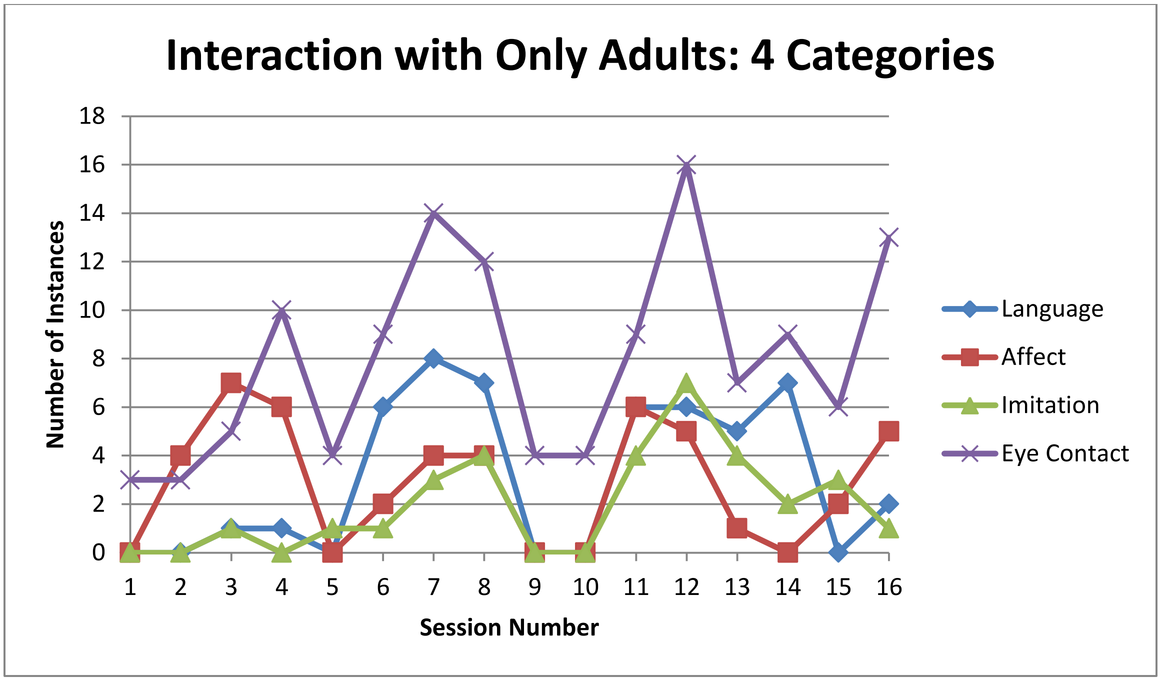

Figure 3. The instances in each session in which Alex initiated social engagement using each of the four categories, *language*, *affect*, *imitation*, and *eye contact*.

Social engagement with the robot. Figure 4 presents the total number of instances in each session in which Alex demonstrated social engagement with the robot. The number of social engagement behaviors generally increased across the sessions with the exception of session 7. During session 7, Alex was very engaged with both the adults and the robot, especially during the initial greeting, songs, and car activity. For example, Troy sang *Popcorn Popping on the Apricot Tree* once and the adults sang the same song three additional times.

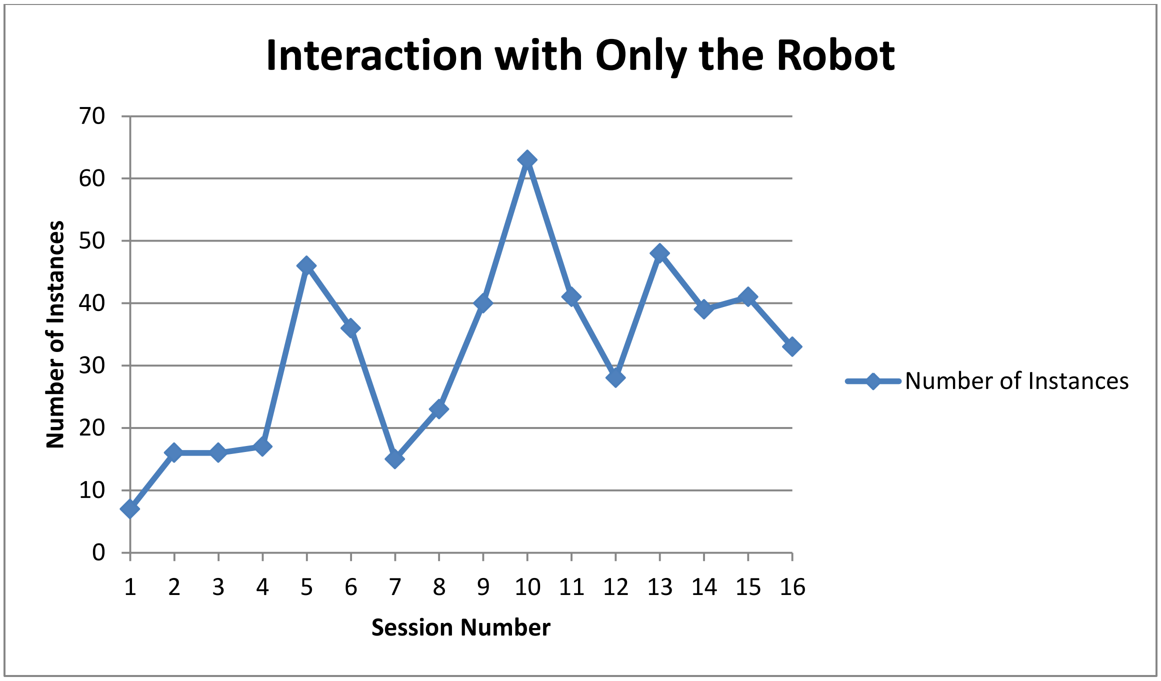

Figure 4. The total number of instances in each session in which Alex demonstrated social engagement with only the robot.

Social engagement with adult and robot. Figure 5 presents the total number of instances in each session in which Alex demonstrated social engagement with an adult and the robot. There were variations from session to session; however, there was an overall increase with the exception of sessions 15 and 16. It is important to note three things that occurred during session 15: (a) Alex was more interested in sitting and staring at Troy even when Troy was not doing anything even though an interaction was going on around the child; (b) Alex's younger sister (about 12 months of age) was part of the interactions; and (c) at one point, the ramp in front of Troy fell apart so the clinician spent some time fixing the ramp. In session 16, Alex became distracted for brief periods of time by the ramp that was in front of Troy; this distraction was removed quickly.

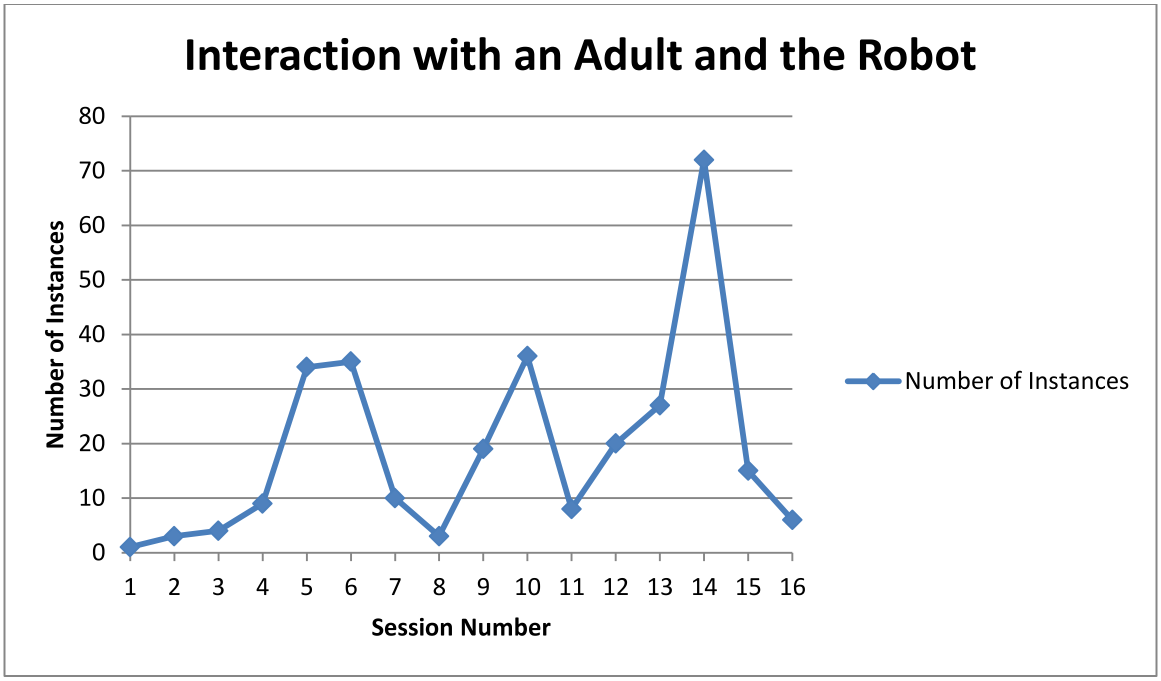

Figure 5. The total number of instances in each session in which Alex demonstrated social engagement with an adult and the robot.

Chris's Performance

Social engagement with the caregiver and/or clinician. Figure 6 presents the total number of instances in each session in which Chris initiated social engagement with the clinicians. There was an overall increase in these behaviors across sessions with the exception of session 8. It is important to note that during session 8, Chris was rarely engaged throughout the entire session. In addition, Chris began displaying unsafe behaviors such as standing on the chairs and the table, thus requiring multiple redirects from the clinician and assisting clinician. During session 14, there was a dip in the number of times Chris initiated engagement. During this session, Chris was highly engaged with the clinician, but most of his engaged behaviors were responding to bids from the clinician rather than initiating engagement.

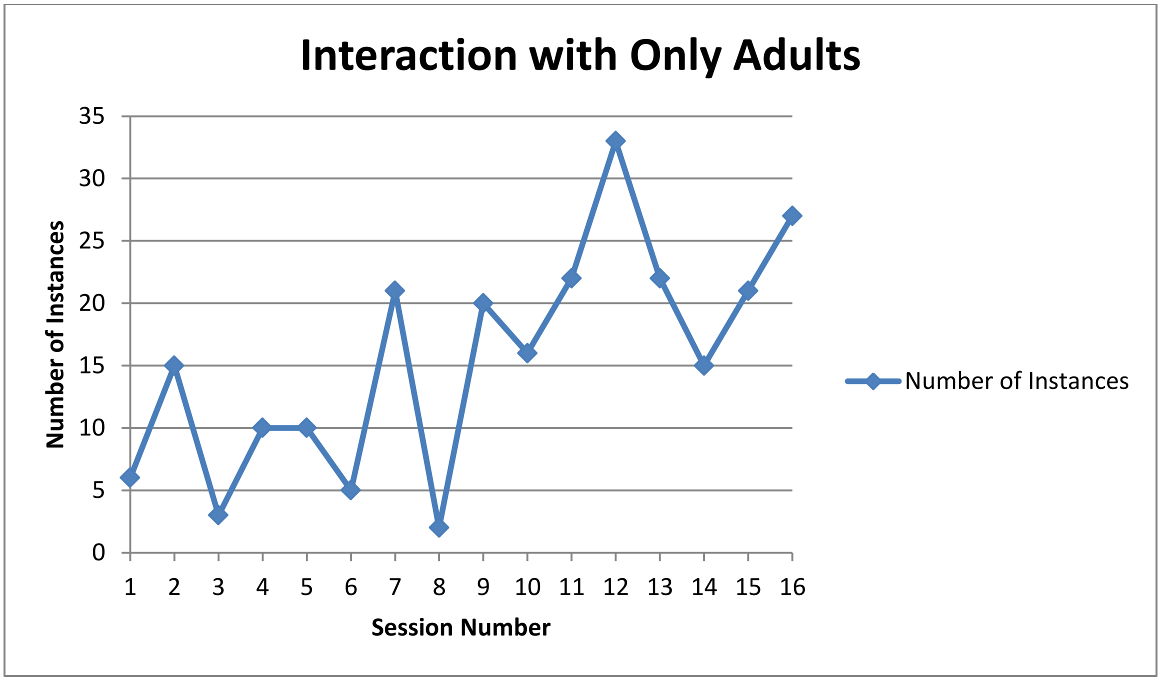

Figure 6. The total number of instances in each session in which Chris initiated social engagement with an adult.

Figure 7 presents the instances in which Chris initiated social engagement using each of the four categories, *language*, *affect*, *imitation*, and *eye contact.* For Chris, the results for the categories *affect* and *imitation* showed little overall change and few fluctuations. In contrast, the categories *eye contact* and *language* showed an overall increase in the number of instances across sessions with the exception of session 8. Again, during session 8, Chris was rarely engaged and was away from the interaction through much of the session. He attempted to walk on the chairs and the table, thus requiring the clinicians to redirect him back to the interaction.

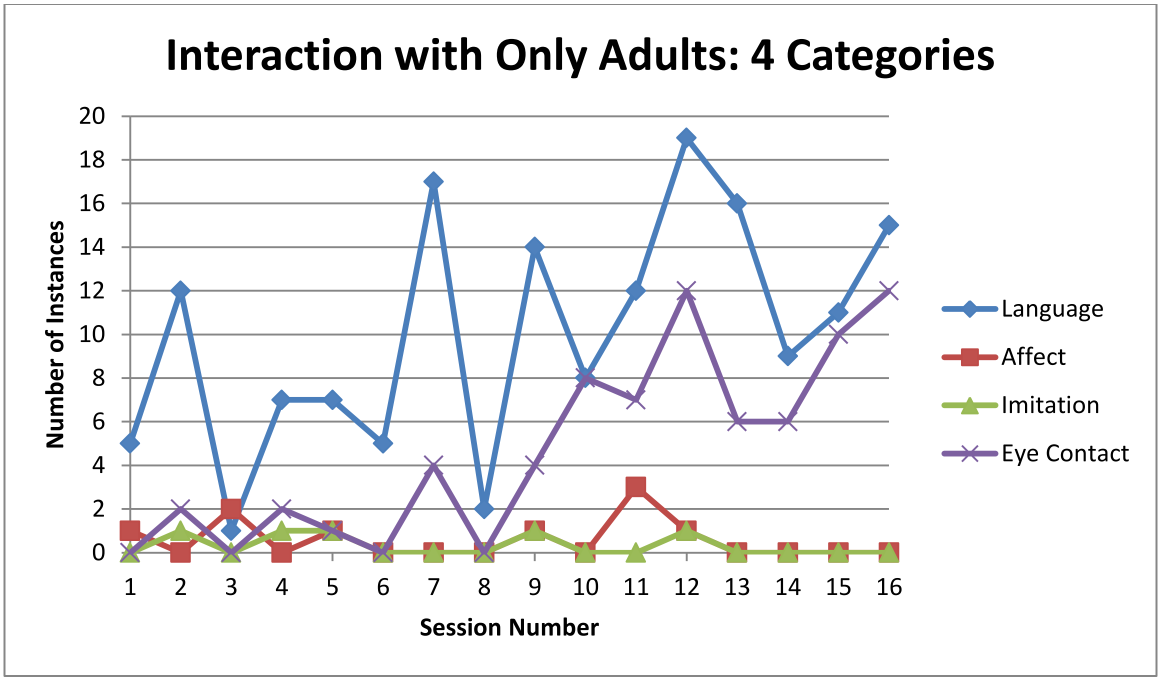

Figure 7. The instances in each session in which Chris initiated social engagement using each of the four categories, *language*, *affect*, *imitation*, and *eye contact.*

Social engagement with the robot. Figure 8 presents the instances in which Chris demonstrated social engagement only with the robot. There was an overall increase from session to session with the exception of session 9. Two of Chris's brothers were present during the session, thus increasing the number of potential communication partners for Chris and decreasing the amount of time with Troy.

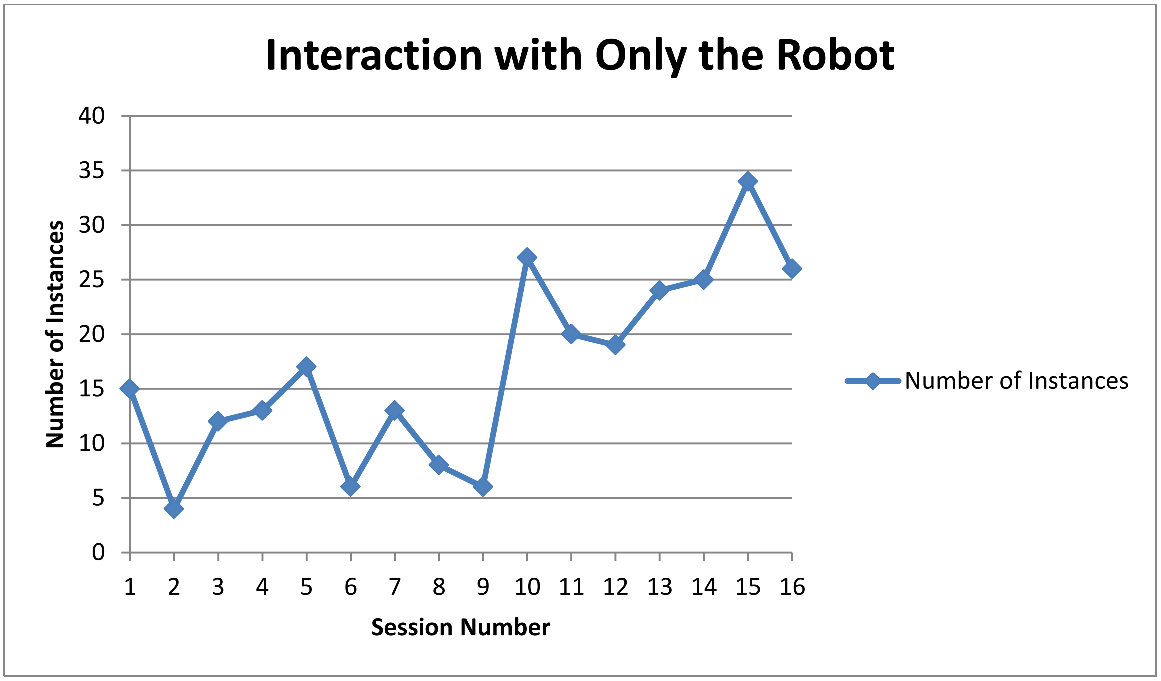

Figure 8. The total number of instances in each session in which Chris demonstrated social engagement with only the robot.

Social engagement with adult and robot. Figure 9 presents the instances in which Chris initiated social engagement with an adult and the robot. Although there were fluctuations between sessions, overall there was a general increase in the total number of interactions. During session 12, instead of using carpet squares to help redirect the child, bean bags were used. In addition, Chris continuously pulled out a LEGO®man from his pocket, which the clinician included into therapy by placing him inside the car they were pushing back and forth. This decreased Chris's focus on Troy and increased his focus on the interaction with the adults. During session 13, Chris was more engaged with the clinicians than with Troy during while singing *Popcorn Popping on the Apricot Tree* (i.e. the clinicians did the actions with Troy and Chris spent more time watching the clinicians rather than Troy).

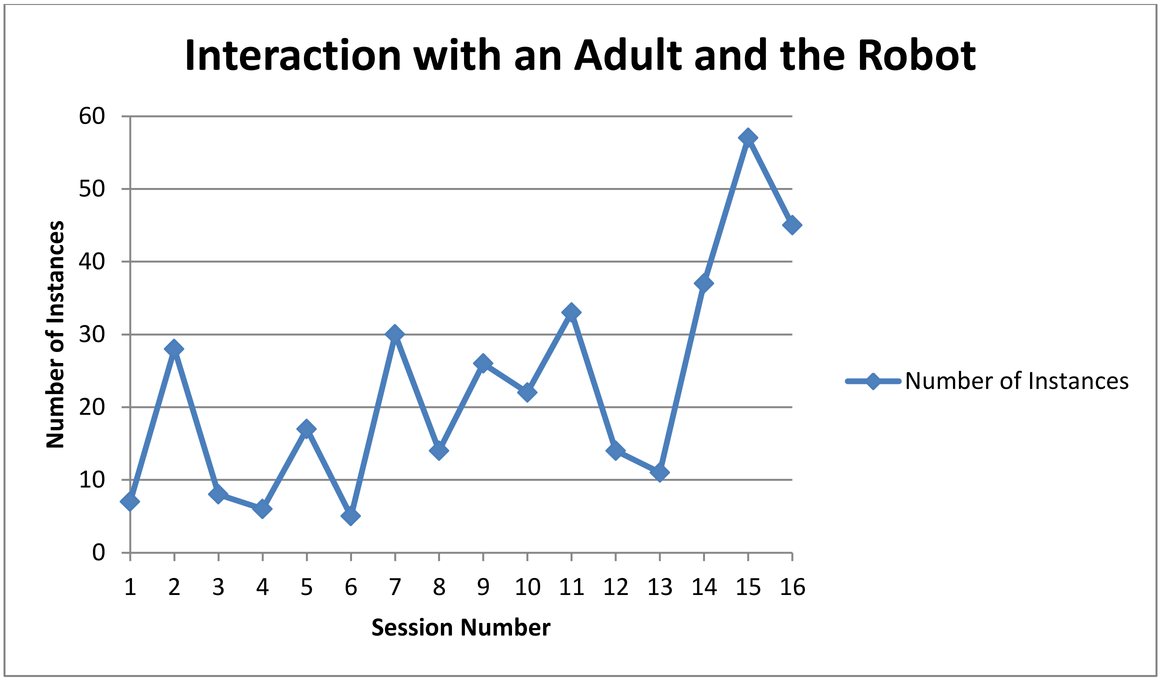

Figure 9. The total number of instances in each session in which Chris demonstrated social engagement with an adult and the robot.

Discussion

This study focused on an intervention in which two children participated in triadic interactions with an adult (clinician or parent) and a robot for short periods of time during more traditional intervention sessions. Although both responding and initiating social engagement behaviors were coded, this paper focused solely on the behaviors that initiated social engagement. The initiations were described based on the partners with whom the child was interacting: the adult, the robot, or both the adult and the robot. The child's initiations to the adult were of the most interest in this study because these behaviors constituted a social connection with the adult, a longstanding intervention focus for both boys. Therefore, initiations directed toward the adults were analyzed in terms of four behaviors, *language*, *affect*, *imitation*, and *eye contact*.

The two children who participated in this study were of different ages (Alex was 3;5 and Chris was 7;11), but they both demonstrated significant levels of disability with deficits in general development as well as in social engagement behaviors. Both children varied in terms of regulation and performance from session to session. For example, Alex often sat by himself while spinning a toy. Chris, on the other hand, had particular challenges with self-regulation; he often ran around the room, bolted for the door, and tried to leave therapy. In addition, both children's level of functioning had been stable over the previous several months to a year; neither one had made notable progress in social interaction, even though they had received intervention.

When the robot was initially introduced in the 10-min treatment sessions, both boys were interested but somewhat hesitant. They initiated very little engagement during the first session. This was not unexpected since they rarely displayed these behaviors previously. In subsequent sessions, however, both children were very interested in the robot, and they both sometimes requested to interact with the robot by going to the door of the robot room. Even though the treatment sessions with the robot were brief (8-12 min), the two children initiated numerous social engagement behaviors within these time segments. In addition, both children began displaying social engagement behaviors that had not previously been observed (e.g. eye contact with the communication partner). Although there was considerable variation in the number of social engagement behaviors children initiated across sessions, it seemed clear that the robot motivated initiation of engagement behaviors, and many of these initiations were directed to the human conversational partners.

Overall, Alex demonstrated gains in initiating social engagement behaviors with the robot and with the adults. His initiation of engagement with adults using eye contact increased markedly. He also initiated using more *affect*, *language*, and *imitation*, although these behaviors varied from session to session. It should be noted that when Alex initiated engagement using *affect*, he shared emotion with his mother or clinician. This sharing of emotion effected a social connection that had rarely been observed before. Both the clinicians and Alex's mother found these moments of shared emotion rewarding.

The robot seemed to play an important role in stimulating Alex's active initiations of social engagement to the robot and to the adults. When involved in activities with the robot, Alex initiated to the adults and although there were fluctuations across sessions, his initiations increased over time. During two sessions (9 and 10), Alex rarely initiated to the adults. During session 9, he was preoccupied with drinking from a sippy cup and did not actively attend to the collaborative activities involving the robot (although he stared at the robot). In session 10, the robot was not working due to technical problems.

Across sessions, Chris continued to show interest in the robot, and he increased in the number of initiations directed to the robot. His interest in the robot did not preclude his initiating to adults, however. In fact, Chris also showed an overall increase in the number of times he initiated social engagement while interacting with adults. The number of times he initiated engagement with adults using *eye contact* increased dramatically. Although there were fluctuations from session to session, Chris also increased his initiations to adults using *language*. In contrast, Chris's initiations using *imitation* and *affect* remained fairly stable across sessions.

Interacting with the robot seemed motivating for each boy. It is important to note that the clinicians conducted the sessions so that interactions with the robot would involve interaction with adults as well. Within this highly collaborative, low dose treatment design, the robot seemed to motivate an increase in the boys' initiations of social engagement. There were, however, 40 min of more traditional, child-centered treatment without the robot. It is possible that the increased engagement behaviors were related to this treatment. This does not seem likely, however, considering that both boys had previously received this type of traditional treatment in the same clinic context for an entire semester. It may have been the case, however, that the brief interaction with the robot combined with the more traditional child-centered approach to effect change. After introduction of the robot in treatment, both boys initiated engagement with adults in ways and frequencies that had not been observed previously.

In considering these findings, it is important to note that multiple factors that could have affected the number of initiations each of the children demonstrated during therapy. A number of internal factors could have been influential. For example, both children had difficulty with regulation, and each child came to the clinic with a different degree of readiness to interact on a given day. There were times where Chris was nonengaged for long periods of time and could not easily be redirected back to the task. On arriving for one session, Chris's brother commented, "Chris is having a bad day." The subsequent treatment session was particularly difficult, thus bearing this impression out.

In addition to issues with self-regulation, the children differed in preferences and interests from day to day. The clinicians varied the activities depending on the interests of the child. The clinicians attempted to incorporate additional activities, but the children sometimes lost interest and retreated from the interaction. The children's preferences often determined how long activities were continued and influenced the amount of time the children were motivated to engage with the adults.

External factors also influenced the children's initiations of social engagement. Both children were occasionally distracted by materials or toys they brought with them. For example, Chris frequently focused on his LEGO®man to the exclusion of other interactions. As mentioned previously, technical difficulties with the robot sometimes interrupted the social exchanges within the session. The social dynamics of sessions altered when a sibling was present or actively participating. This was not necessarily a disadvantage, however. For Chris, having his two brothers in the room helped him to refocus back to the interaction and gave him additional communication partners with whom to interact. On the other hand, when Alex's younger sister (age about 12 months) became involved in some of the activities, she sometimes reached for or took Alex's toy. Additional external factors may have influenced the interactions as well.

The findings of these case studies support the following conclusions. First, both children showed interest in and engaged with the robot. Both Alex and Chris showed positive affect while interacting with Troy thus indicating their interest in the robot. Second, the results indicated that both children did not initiate exclusively with the robot. The children collaborated with the robot *and* the adults. Third, the children demonstrated behaviors that had not been seen previously. For example, in Chris's final session he made requests for a specific activity while making eye contact with the clinician.

The low-dose, highly interactive sessions using the robot seemed effective in motivating the two children to initiate social engagement with adults. The intervention was approached as a case study, however, and results observed may not generalize to other children. It is not clear to what extent possible additional internal or external factors may have influenced the children's behavior. The current work is only preliminary, but subsequent research seems warranted to investigate the potential of robots to facilitate social engagement in children with ASD.

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Appendix A

Annotated Bibliography

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

Purpose of the study: Acerson evaluated pre- and post- assessments after intervention using a humanoid robot, Troy. Treatment with the robot was low-dose in that interactions were roughly 8-10 min in length.

Method:
Participants: Participants included two children with ASD. Both children had been observed at the Brigham Young University Clinic for the year prior to this study. Neither of the children had made significant progress in joint attention and social engagement behaviors.

Procedures/Assessment Instruments: Two particular interactions were evaluated: child-parent play and a child-clinician play. Triadic interactions were used in intervention with the robot across 16 sessions. Pre- and post- intervention assessments were recorded and coded according to the social engagement behaviors demonstrated by the children. Clinical observations before and after intervention were also reported.

Results: One child demonstrated gains in social engagement behaviors during post-intervention assessments. The other child increased in some behaviors and decreased in other behaviors post-treatment. Clinical observations suggested increased interactions in both children.

Conclusions: Both children engaged in interactions with the robot. Results were dramatic for one child and variable for the other. Factors such as the parents' interactional style were influential. Clinical observations suggested that the robot seemed to motivate instances of interaction that had not been observed previously.

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

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

Purpose of the work: This article reviewed procedures for screening and early identification of children with autism. Because of the increasing prevalence of children with autism, there is a need for such an identification system.

Summary: The particular identification system reviewed in this article was created by a panel of members from the American Academy of Neurology (AAN). These guidelines "[identify] two levels of investigation that are necessary to clinically identify children with autism" (p. 534). The first of these levels, the "Routine Developmental Surveillance," identifies children at risk for delays in development and then identifies which of these children is at risk for autism. Studies have shown that behaviors recognized in children with autism are measurable after the age of 18 months. Some of these behaviors include difficulty with eye contact, pretend play, and joint attention. Blackwell stressed the importance of screening for autism "on all children who fail a routine developmental screening" (p. 535).

The second level, the "Diagnosis and Evaluation of Autism," requires a more in-depth assessment of the children previously identified in the first level, thus helping to differentiate between autism and other developmental disorders. The AAN stressed the importance of having an experienced clinician assess the child at risk for autism using these guidelines as well as other rating scales and checklists.

A list of recommendations was included in the guidelines. These recommendations included the following: 1) allowing ample time for parent interviews regarding current concerns; 2) observing behaviors (especially social and communicative); 3) "…[using] recommended diagnostic parental and observation instruments" (p. 535); 4) reevaluating the child within one year of the initial diagnosis and continuing to monitor behaviors; and 5) assessing the family's knowledge and understanding regarding the child's condition.

Conclusions: Blackwell concluded that pediatric healthcare providers need to increase their understanding and knowledge of autism. This knowledge helps in early diagnosis and intervention for children at risk for autism.

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

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

Purpose of the work: This article discussed possible advantages of using a robot to interact with children with autism as a complement to therapy. The researchers also discussed the difficulties in creating an effective robot for therapy.

Summary: The authors list possible advantages of using robots in therapy for children with autism. First, robots are less intimidating than humans for children with autism. Children may feel more comfortable and relaxed while interacting with a robot. They may enjoy the interaction and learn from it. Second, the robot acts in a predictable manner. Children with autism often become uncomfortable when situations are unpredictable so a robot that is programmed to act consistently might help children to feel more at ease. As a child begins to adapt to the robot, the robot is programmed to increase in complexity and to introduce new elements of interaction. Third, a robot's repertoire is limited and simplifies the amount of communication information the child must process. Fourth, previous research has suggested that children with disabilities enjoy interacting with computers.

Blomgren and Tenggren focused on difficulties with turn-taking and imitation. They argued that these skills constituted a significant deficit for children with autism. They reasoned that turn-taking and imitation skills were prerequisite to other communicative skills.

Blomgren and Tenggren also discussed aspects of the robot prototype. First, the robot was able to express basic emotions through facial expressions and/or sounds. Because of the wide range of communicative skills on the spectrum, the robot needed to be flexible to provide the best interaction for the particular child. The robot then prompted the child to identify the emotion the robot expressed by touching an image of the robot on the screen. (The illustrations could be changed to fit the child's specific needs.) If the child's choice was correct, the robot rewarded the child. These rewards could be adjusted for each child (e.g., music).

Children with autism tend to be drawn to lights, details, and bright colors, but these can distract children and undermine the effectiveness of the interaction. The researchers created a prototype that took this consideration into account. The researchers were also concerned that the robot remained unbreakable even when roughly handled by the child.

The researchers created a robot that was intended to be used in a controlled environment with a professional nearby. This professional was important because they adjusted the robot to adapt to the child's needs. Each session was brief, roughly 5-10 min.

When designing the robot, Blomgren and Tenggren recognized that the robot needed to have a "participatory" design (p. 5). Because individuals with autism typically have other developmental disabilities as well, they typically need a person to guide them through the design. In addition, feedback on the robot's effectiveness was acquired from observers.

In previous research, Jonsson and Anderberg created "three different methods for developing functionality in technical aids for disabled people" (p. 6). They are referred to as the parrot method and the chameleon method. Blomgren and Tenggren decided to use the first two methods, the parrot and the chameleon. The parrot method used imitation techniques to teach social interactions. The chameleon method implied "solving a problem using a completely different solution" (p. 6). Blomgren and Tenggren used robotic technology in rehabilitative therapy.

There were formative and summative steps in the evaluation process. The formative process required professionals to create a robot that was usable for the group they were researching (in this case, children with autism). The summative process changed anything that needed to be corrected about the design.

Conclusions: Blomgren and Tenggren described both difficulties and challenges in using robotics to treat children with autism. They described characteristics of robot design and considerations for the use of robots in therapy.

Relevance to the current work: This study provided rationale for using socially assistive robots in treatment for children with ASD as well as processes to design and implement treatment using 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 work: Bruinsma et al. reviewed literature on joint attention skills of children with autism. The researchers noted that joint attention refers to a group of behaviors that "share a common goal of communicating with another person about a third entity in a nonverbal way" (p. 169). Examples included eye gaze and gestures. The authors divided joint attention into two types, response to joint attention (RJA) and initiation of joint attention (IJA). This research article focused mainly on initiation of joint attention.

Summary: Typical children demonstrated a relationship in the development of joint attention skills "with the development of intentional communication" (p. 169). [*Intentional communication* was defined by three characteristics: 1) joint attention (particularly eye gaze), 2) child's persistence, and 3) child's vocalizations (resembling speech patterns) (p. 170).] As the child developed, these behaviors become more "purposeful" and "goal directed" (p. 169). The researchers hypothesized this occurred "as a result of parents or other communicative partners attributing meaning to actions" (p. 169).

Previous research demonstrated that the development of IJA in typical children was critical to language acquisition. As a child demonstrated joint attention, his or her communication included not only the communication partner but the object as well. Research has shown that children with autism demonstrated a deficit in IJA, and their greatest difficulty of joint attention was eye contact.

Typical children used three types of communicative acts: 1) behavior regulation, 2) social interaction, and 3) joint attention. Children with autism, however, only demonstrated communication for requesting and protesting, not for social purposes. Researchers have discovered a "strong relationship between the child's developing lexicon and the amount of time spent in joint attention episodes" (p. 172). Joint attention behaviors (e.g., eye gaze, nonverbal requesting, commenting) "[made] up intentional communication [and was] of considerable interest in light of their roles as precursors to the acquisition of first words" (p. 172).

Conclusions: One important finding from this research was the positive correlation "between the amount of time in joint attention episodes and size of expressive vocabulary at later ages" (p. 172). A characteristic of autism was a "lack of communicative competence" (p. 173) which could be attributed to the fact that individuals with autism have a tendency to develop language later and at slower rates. The researchers concluded it is important not to underestimate the importance of intentional communication through verbalizations, joint attention, and attention to cues.

Relevance to the current work: This article described the development of joint attention skills and how they impacted development.

Campolo, D., Taffoni, F., Schiavone, G., Laschi, C., Keller, F., & Guglielmelli, E. (2008,

August). *A novel technological approach towards the early diagnosis of neurodevelopmental disorders*. Paper presented at the 30th Annual International IEEE EMBS Conference, Vancouver.

Purpose of the study: The authors aimed to develop methods for obtaining "more information on perceptual and intersubjective capacities of human infants than…currently possible" (p. 4875). Neuro-Developmental Engineering (NDE) is a relatively new field of research. NDE researchers attempt to more fully understand the neuro-biological system of the development of the human brain, create a method to quantitatively gather data on human behavior during development, and assess developmental milestones achieved by humans throughout life. Research obtained helps companies create educational interactive toys that more fully aid in neurological development of young children. One particular research study was the Thought-in-Action (TACT) project. This project aimed to establish a standard in which infants at risk for certain neuro-developmental disorders (especially autism) could be quantitatively measured and detected earlier in their development. The authors discussed skills children with autism lack in social interactions, language, and communication. Therefore, a standardized method for detecting these deficits early in development helped determine the need for early intervention.

Method:
Procedures/Assessment Instrumentation: There were three requirements for the created technology. First, the instruments needed to remain inconspicuous while the infant was continuously monitored. This meant the instrument had to be small, lightweight, wireless, and portable. Second, the instrument had to be cost-effective so researchers could test large groups of individuals. Third, the instrument could not require a highly structured environment.

Campolo et al. used three instruments to collect data. First, was the MAG3 device due to its minimal alignment errors and its appropriate size. Second, Campolo et al. developed the *Wrist and Ankle Movement Sensors* (WAMS). Data collected by the WAMS were digitally converted and transmitted wirelessly to the computer. Third, the Audio-Visuo-Vestibular Cap (AVVC) was used. This device contained three different types of sensors. These sensors measured the orientation of the head, the eye gaze of the infant, and sound localization (via two microphones).

Results: Campolo et al. released the first prototypes of the technology described and placed them in four infant centers in Europe.

Conclusions: Lowcost devices were important to screening large groups of infants. Campolo et al. anticipated that the most difficult part of this project would be to analyze and interpret the data.

Relevance to the current work: This article explained different ways to obtain objective data while using a socially assistive robot in therapy.

Conti-Ramsden, G., Simkin, Z., & Botting, N. (2006). The prevalence of autistic spectrum disorders in adolescents with a history of specific language impairment (SLI). *Journal of Child Psychology and Psychiatry*, *47*(6), 621-628. doi: 10.1111/j.1469-7610.2005.01584.x

Purpose of the study: Both Specific Language Impairment (SLI) and Autism are developmental disorders that involve language difficulties; however, autism is currently defined to include difficulties in social contexts. Conti-Ramsden and colleagues challenged the notion that SLI and Autism are two distinct disorders and suggested there is a connection between them.

Method:
Participants: This study compared data obtained from seventy-six 14-year-olds who met Conti-Ramsden et al.'s criteria for SLI.

Procedures/Assessment Instrumentation: Conti-Ramsden et al. conducted six measures to determine if the individual with SLI could also be identified with autism. Measures included the following: *Autism Diagnostic Interview-Revised (ADI-R), Autism Diagnostic Observation Schedule (ADOS), Family History Interview (FHI), WISC-III, CELF-R,* and *Wechsler Objective Reading Dimensions (WORD).*

Results: The results from these measures showed a majority of the individuals did not demonstrate characteristics that would classify them as having autism; however, 3.9% of children assessed were considered to demonstrate autism characteristics by both the *ADI-R* and the *ADOS*. These results were about 10 times more than what would be expected in the general population. In addition, there were a significant number of individuals who met the criteria for autism in at least one of the 2 measures, either *ADI-R* or the *ADOS* (26.4%).

The results of this study suggested there is an increased risk of autism (10 times more) in individuals who have been diagnosed with SLI.

Conclusions: Clinicians must be aware of this increased risk of autism in individuals with a history of SLI. When diagnosing language disorders, the clinician can ensure to include specific autism diagnostic assessments.

Relevance to the current work: This study suggested co-occurrence of autism and SLI. The two participants in the current study demonstrated significant language problems in addition to other characteristics of ASD.

Dapretto, M., Davies, M. S., Pfeifer, J. H., Scott, A. A., Sigman, M., Bookheimer, S. Y., & Iacoboni, M. (2005). Understanding emotions in others: Mirror neuron dysfunction in children with autism spectrum disorders. *Nature Neuroscience, 9*(1), 28-30. doi: 10.1038/nn1611

Purpose of the study: Previous studies have shown that mirror neurons fire not only when an individual himself is performing an action but also when the individual observes the same action done by another. Recent studies added that the mirror neurons in individuals with ASD may not function in this manner. This study tested these hypotheses.

Method:

Participants: Dapretto et al. designed a study involving fMRI observation of 20 children: 10 high-functioning children with ASD and 10 typically developing children (with matched age and IQ). These children were observed during an activity of imitating or viewing facial expressions of emotion.

Procedures/Assessment Instrumentation: Five different emotions (anger, fear, happiness, neutrality, or sadness) expressed in 80 faces were individually flashed in front of the child for 2 s. The child had previously been instructed to either imitate the expressed emotion or observe the emotion.

Results: The researchers observed that the children with ASD attended to the stimuli and imitated the emotions, but the fMRI data showed that the children lacked firing of the mirror neurons in the pars opercularis. This finding validated Dapretto et al.'s hypothesis that individuals with ASD demonstrated different firings of mirror neurons in the brain. In addition the researchers looked at the relationship between activity of mirror neurons and symptom severity. The researchers discovered that the higher the activity in this area of mirror neurons during imitation, the higher the child's level of social functioning.

Conclusions: These results provided strong evidence that early dysfunction in mirror neuron systems may be the underlying cause of social deficits in individuals with ASD.

Relevance to the current work: This study suggested causal factors for the difficulties individuals with ASD have with emotional understanding.

Duffy, B. R. (2004). The social robot paradox. Retrieved from http://www.cs.ucd.ie/csprism/publications/pub2004/

Purpose of the work: Duffy discussed issues involving the social robot paradox in order to more clearly define the term. Some of these issues included the following: can a robot ever become part of our social circle, and at one point does the robot become more than a tool? The question of the social robot paradox is thus: if non-humanoid robots have been so successful in industrial work and humanoids have only been produced as elaborate toys, why should a social robot be built?

Summary: Research has shown if a robot is given attributes that make it more human-like (such as a name) it increases the likelihood an individual will develop a relationship with it. Research also showed if a robot appears too knowledgeable in the characteristics of social interactions, the interactions may be too similar to exchanges we experience between humans than we may be comfortable with. The question at this point became *what is the purpose of the robot?*.

Conclusions: Duffy concluded that the ideal robot balances the realistic qualities of human interactions while it maintains its machine-like characteristics. In addition, if the robot was created with the intent of social interactions then it was imperative that an individual could develop a relationship with the robot.

Relevance to the current work: This article discussed issues important to interacting with socially assistive robots.

Edsinger, A., O'Reilly, U., & Breazeal, C. (2000, September). Personality through faces for humanoid robots. Paper presented at the IEEE International Workshop on Robot and Human Interactive Communication, Osaka. 340-345.

Purpose of the study: This study determined which features best express the appearance of an iconic, 5 to 6 year old child. A spectrum assigned to robots compared the facial similarities to a human face with caricature. The middle area of this spectrum was termed *iconic*. Edsinger et al. wanted to create a robot that fell in this middle ground.

Method: The researchers' aimed to design a robot that "[provided] the critical facial cues such that the physical features of the head are suggested, the intended morphology is understood, yet the features are not so defined that the human viewer creates rigid social expectations that the robot cannot meet" (p. 341). The researchers hypothesized that the set of expectations the viewer created for the robot defined how the human would interact with it. Research has shown that "humans generally treat computers as they might treat other people" (p. 341).

The researchers stressed it is imperative to choose eyes that have the correct proportion and are conspicuous because eyes are a focal point of a human-robot social interaction. The researchers experienced difficulties in creating a neutral face (in terms of gender and race) while still including a bias in the age and morphology. The morphology influenced the viewers' perception and expectation of the social and physical abilities of the robot.

Results: At the time this paper was written, the researchers had only completed one step towards this goal. They used a technique that rapidly builds prototypes of robot designs called the Stereolithography (SLA) technique.

Conclusions: After the completion of the first step, the researchers emphasized the importance of the robot's facial features in social interactions. The researchers stated progressive steps will include an evaluation of the importance of moving eyebrows, eyelids, and lips.

Relevance to the current work: This article described strategies for creating facial characteristics of socially assistive robots.

Gaffan, E. A., Martins, C., Healy, S., & Murray, L. (2009). Early social experience and individual differences in infants' joint attention. *Social Development,* 19(2), 369-393. doi: 10.1111/j.1467-9507.2008.00533.x

Purpose of the study: Gaffan, Martins, Healy, & Murray aimed to discover the factors that help typically developing infants develop joint attention (JA) skills. In order to study these factors, a triadic interaction (involving the child, an adult, and a toy) was used. This type of interaction allowed the researchers to ask "whether individual variation in JA at nine months of age could be accounted for by differences in mothers' interactive style at the earlier age-points, or alternatively by infant characteristics or other variables" (p. 369).

Previous studies involved children above the age of nine months. This study was developed so the “early precursors of JA” (p. 370) could be examined and compared to infants over nine months of age. Research has shown that by the age of nine months, the infant is able to be purposeful and understand not only their own intentions, but the intentions of others as well (Tomasello, 1995, 1999; and Tomasello et al., 2005). Gaffan, Martins, Healy, and Murray examined qualitative changes that occur around the age of nine months. In addition, they “analyse[d] whether concurrent adult behavior (by mother or researcher) during nine-month interactions affect[ed] infant participation in JA” (p. 373).

Method:
Participants: One-hundred and thirteen mothers (ranging in age from 20-40yrs) with their newborn full-term infants were recruited for this study. Fifty-eight of these mothers were diagnosed with Post-partum depression (PD) and the remaining 55 mothers scored low on the PD screening (the control group). A random sample (n=59) of the 113 mothers participated in the mother-infant interactions portion of the study. Twenty-nine of these mothers experienced PD and 30 did not.

Procedures/Assessment Instruments: The 59 mothers and their infants were filmed for an assessment at 2 months, 4 months, 6 months, and 9 months. During each assessment, an interview was completed to assess any depressive symptoms in the mother. In addition, face-to-face interactions were recorded for each age. Toy-play interactions were also included in the assessment at 6 and 9 months. There were 2 hidden cameras used to record the interaction. One captured the full-face of the infant and the other captured the full-face of the adult.

For the 2 and 4 month assessment, the mother initially sat opposite the child and played with the child for 5 min (without using toys). Then, the researcher interacted with the infant for an additional 5 min. The researcher attempted to elicit JA with the child during this time.

For the 6 and 9 month assessment, the mother again played with the infant for 5 min with only the aid of a cloth (i.e. for ‘peekaboo’ games). The next 5 min consisted of mother-infant toy-play using a particular age-appropriate toy. After this second 5-min interaction, the researcher interacted with the child for an additional 5 min. The researcher played naturally with the child without attempting to elicit any particular behaviors, including JA.

The interactions were then coded using two methods for each age group: coding moment-to-moment of the interactions with the infant and the adult and a global rating scale (from 1-5) of the infant’s interactions with the two adults. The videos were coded using *The Observer* software (Noldus, Wageningen, The Netherlands). Additional measures included: *Stage IV Object Permanence* (Wishart and Bower, 1984), *Edinburgh Postnatal Depression Scale* (Cox, Holden, & Sagovsky, 1987), and *Socioeconomic Status (SES)* (Registrar-General, 1980).

Conclusions: Gaffan et al.’s research findings “impl[ied] that social learning models should take into account specific adult actions, and their co-ordination with infant actions” (p. 391).

Relevance to current work: The article described different aspects of joint attention in typically developing children, thus giving this study a basis for comparison to children with ASD.

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

Purpose of the work: This paper discussed the types of technological advances in therapy for children with autism. In addition, Goldsmith and LeBlanc included recommendations for future research. Goldsmith and LeBlanc focused on a technology-based intervention design which uses technology as a "temporary instructional aid to be removed once the goal of behavior change has been met" (p. 166).

Summary: Individuals with autism require assistance and prompts to help them regulate their behaviors. Examples of typical prompts include vocal, signed, and gestural. Research has shown that prompts can be effective in various ways and are used for various reasons. Currently, some prompting devices have the same prompting abilities as humans. Goldsmith and LeBlanc divided these devices into two categories based on the type of prompting they exhibit: auditory and tactile. Research has shown that tactile stimulation is more effective than auditory prompts to help children with autism complete tasks.

There are five types of technological devices created for temporary use in intervention: "tactile and auditory prompting devices, video-based instruction and feedback, computer-aided instruction, virtual reality, and robotics" (p. 166).

First, tactile and auditory stimulation have been used to prompt children with autism. These devices require a second person within close proximity to the child in order for the prompt to be successful. An example of this type of prompt is a vibrating device used to initiate play.

Second, Goldsmith and LeBlanc discussed video technology. Currently, video technology is the most widely used, accepted, and available forms of technology for instructing children with autism. Video technology is most frequently used as a model and to teach individuals with autism appropriate conversational and social skills.

Third, computers were used to teach many important skills to children with autism. Some of these important skills included: predicting emotions, increasing vocabulary, improving problem solving skills and social skills, and enhancing imitation. Research has shown that computer-based interventions not only improved targeted skills, but also increased attention and motivation.

Fourth, virtual reality is used to create "a three-dimensional, computer-generated world in which people can behave and encounter responses to their behavior" (p. 171). There have been studies focusing on the use of virtual reality in intervention for children with autism that have had positive results; however, additional, larger studies must be completed in order to generalize these findings.

Fifth, research has suggested that robotics benefited children with autism. Researchers hypothesized this for two reasons: the social environment was simplified and the interactions were predictable. This allowed the individual to practice the same interactions more than once while slowly increasing the complexity. The child learned important social skills and behaviors from the interactions with the robot. The Aurora Project led by Kerstin Dautenhahn suggested that "(a) robots are safe interaction partners for children, (b) children are not afraid of the robot, (c) children are sufficiently motivated to interact with the robot over a period of 10 min or longer, (d) children are more interested in the robot in 'reactive' mode as compared to the robot showing rigid, repetitive, non-interactive behavior, and (e) children show no distress or behavior problems when the robot behaves reactively but not completely predictably" (p. 172). The use of technological devices in intervention has potential for becoming an effective tool in therapy for children with autism; however, more research needs to be completed.

Conclusions: Mechanical prompting devices, video, computers, virtual reality, and robotics have potential in intervention for children with autism; however, Goldsmith and LeBlanc posed the question of efficacy and cost-effectiveness. They believed that research needs to focus on determining if these technological therapeutic interventions are cost-effective and more effective than traditional, "low-tech interventions" (p. 173). In addition, Goldsmith and LeBlanc stressed the importance that these high-tech devices need to be user-friendly.

Relevance to the current work: This article discussed the potential of socially assistive robots in intervention for children with autism.

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

Purpose of the study: Goodrich, Colton, Brinton, and Fujiki described social engagement behavior in child-human interactions.

Method:
Participants: Two children with ASD were involved in collaborative interaction sequences including a robot and adult(s) for 10 min of a 50- min therapy session across 16 sessions.

Procedures/Assessment Instruments: Social engagement behaviors from the pre- and post-intervention assessments were coded. Assessments included interactions between each child and a familiar adult, an unfamiliar adult, and a triadic interaction with two graduate clinicians.

Results: Both children demonstrated an increase in the number of initiating engagement behaviors during the post-intervention assessments.

Conclusions: The results from this study were promising. A future study involving four children with autism will begin in January 2011. This study will incorporate a staggered start approach in order to better measure changes in social engagement behaviors.

Relevance to the current work: The results from this study were promising and suggested that additional investigation is warranted.

Hansen, 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: Hansen evaluated pre- and post- assessments after intervention using a humanoid robot, Troy. Treatment with the robot was low-dose in that interactions were roughly 8-10 min in length.

Method:
Participants: Participants included two children with ASD. Both children had been observed at the Brigham Young University Clinic for the year prior to this study. Neither of the children had made significant progress in joint attention and social engagement behaviors.

Procedures/Assessment Instruments: Two particular interactions were evaluated: interactions with two adults and an interaction with an unfamiliar adult. Triadic interactions were used in intervention with the robot across 16 sessions. Pre- and post- intervention assessments were recorded and coded according to the social engagement behaviors demonstrated by the children.

Results: Both children demonstrated gains in social engagement behaviors during post-intervention assessments. One child demonstrated a more marked increase in these behaviors.

Conclusions: Results of the case studies suggested that the low-dose, interactive intervention using a robot resulted in increased interactions with human interactional partners.

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

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

Purpose of the study: This study focused on the effectiveness of interventions targeting joint attention and symbolic play.

Method:
Participants: Participants in the study were selected from an early intervention program. Fifty-eight children diagnosed with autism (3-4 years of age) participated. Forty-six of the children were male.

Procedures/Assessment Instruments: Pre- and post- intervention assessments were completed. These assessments focused on joint attention skills and mother-child interactions. Initial assessments included the ADOS, the ADI-R, the Mullen Scales of Early Learning, the Reynell Developmental Language Scales, the Early Social-Communication Scales, and the Structured Play Assessment.

Participants were randomly placed into one of three groups: joint attention intervention, symbolic play intervention, or a control group. Twenty children were placed in the joint attention group, 21 children were in the play group, and 17 children were in the control group. Interactions were 30 min daily for 5-6 weeks.

The initial assessments were repeated post-intervention except the ADOS and the ADI-R. These assessments were recorded and later scored based on the number of initiations and responses to joint attention.

Results: Results indicated that children in both intervention groups improved more significantly than children in the control group. Children in the joint attention intervention demonstrated significant improvements in initiating engagement and responsiveness to engagement during the post-assessments. Children in the symbolic play intervention demonstrated more diverse forms of symbolic play during post-assessments.

Conclusions: The positive results showed the possibility for generalization of joint attention and symbolic play skills in children with autism. Further research targeting the long-term effects of intervention is warranted.

Relevance to the current work: The coding procedure used to identify joint attention served as the basis for the analysis of social engagement in the current study.

Kozima, H., Nakagawa, C., Kawai, N., Kosugi, D., & Yano, Y. (2004). A humanoid in company with children. 470-477.

Purpose of the study: Kozima et al. described observations comparing the interactions between 14 normal children and a robot to a child with autism and a robot. This humanoid produced facial expressions, moved its lips, analyzed speech sounds (i.e., emotional prosody), and imitated vocalizations. In addition, the humanoid made eye-contact and attended to the interaction.

Method:
Participants: The researchers observed 14 normal children interacting with the humanoid. This group of children varied in age from 6 months to 9 years. The child with autism was 6 years of age. He exhibited verbal and nonverbal intelligence in the normal range, but he showed deficits in social communication.

Procedures/Assessment Instruments: The humanoid alternated between eye-contact and joint attention (i.e., pointing). Observations were divided into three stages: the neophobia phase, the exploration phase, and the interaction phase.

The child with high-functioning autism was placed in the room with the humanoid and left alone to interact with it for 3 to 4 min. Then, the child’s mother entered the room and sat with the child during the remainder of the interaction. The interaction lasted for roughly 30 min on average (i.e., when the child became tired).

Results: During the neophobia phase, the typical child stared intently into the robot's eyes and then became flustered because he/she did not know how to interact with the humanoid. The exploration phase typically began when the typical child's mother entered the room. During this phase, the child began to explore the robot's abilities and responses. The interaction phase occurred when the typical child increased his/her social interaction(s) with the robot (e.g., verbal interactions such as questions or declaratives).

The child with autism exhibited the following: the child demonstrated the neophobia phase for the first 45-min in the same fashion as the normal children. During the interaction phase, the child demonstrated "everyday social actions (such as giving, showing, and asking)…[and] an *ad lib* game and hide-and-seek" (p. 476).

Conclusions: The researchers reported that "Although his way of playing with [the humanoid was] still in his own style, this would tell us a lot about his developmental profile" (p. 476).

Relevance to the current work: This article discussed interactions between a child with autism and a socially assistive robot.

Lee, J. K., Toscano, R. L., Stiehl, W. D., & Breazeal, C. (2008, August). The design of a semi-autonomous robot avatar for family communication and education. Paper presented at the IEEE International Symposium on Robot and Human Interactive Communication, Munich. 166-173.

Purpose of the work: Lee et al. discussed two specific scenarios in which the robot can add to the communication process. The first scenario used the robot as a form of social communication between two people (e.g., family members) separated by great distances. The researchers stressed that this particular robot is semi-autonomous in structure (i.e., the robot is capable of directing attention through means such as pointing), thus more effectively engaging both communication partners. The second scenario's focus was geared for educational purposes. The child sat at a computer with the semi-autonomous robot (controlled by a remote teacher) to learn the lesson.

Summary: The researchers discussed six elements necessary for a successful communication robot. First, the robot must allow the operator to direct the attention or respond to the users' attempts to direct the attention of the robot. Second, the operator and the user must share attention easily and must focus on the same object. Third, the robot must provide understandable real-time data to enable the operator to be more immersed in the interaction. Fourth, the robot must be easy to control and help to decrease the cognitive load of the operator, but the robot must allow for "rich forms of expression (vocalizations, facial expressions, gestures, etc.)" (p. 167). Fifth, the robot must be readable to the user (i.e., in expressions, behaviors, and personality). Finally, the mode of communication between the operator and the robot must be widely accessible (e.g., the internet).

Conclusions: Recent studies used robots to teach social communication skills in children who lack them (e.g., a child with autism). The rise in technology use increased the need to create a successful communication robot that may be used for therapeutic purposes.

Relevance to the current work: This article described the current technological advances in socially assistive robotics.

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

Purpose of the study: Miyamoto et al. conducted a 6-month longitudinal study of social interactions between children with autism and robots. They focused on the children's "persistence in fixed patterns of actions" (p. 145).

Method:
Participants: Five children with autism participated in this study (2 males and 3 females).

Procedures/Assessment Instrumentation: The robot performed two tasks: simple verbal phrases and "without speaking acts…(e.g., pushing/bringing objects)" (p. 145). The children participated in 5 monthly sessions for 5-10 min. The robots were controlled wirelessly from another room while the teacher remained in the room with the robot and the child.

Results: Only two of the five children interacted with the robot. The results showed that both children "came to direct the experimental environments in a specific way and the robots destructed their patterns into more social ones…[however,] under these constraints new actions emerged" (p. 146). The other three children did not interact with the robot.

Conclusions: This finding suggested that robots can socially communicate with children with autism.

Relevance to the current work: This article discussed interactions between children with autism and socially assistive robots.

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 and Allied Disciplines, 27*(5), 657-669.

Purpose of the study: This study compared social behaviors of young children with mental retardation to those of children with autism. Children with autism exhibited social skills deficits different from children with mental retardation (i.e. particularly in the areas of non-verbal affiliative, indicating, and requesting behaviors). Additionally, non-verbal skills and object play skills of typical children, children with mental retardation, and children with autism were compared.

Background information: Previous studies divided non-verbal social communication techniques into three categories: affiliation, joint attention, and behavior regulation. Affiliation, or social interaction, included non-verbal acts to maintain face-to-face interaction. Joint attention or "indicating behaviors" (p. 657), were defined as "the use of procedures (e.g.

showing a toy) to co-ordinate attention between interactive social partners with respect to objects or events in order to share an awareness of the objects or events" (p. 657). Behavior regulation or "*requesting* behaviors" (p. 658) were defined as "the use of procedures (e.g. reaching to toys) to co-ordinate attention between interactive partners with respect to objects or events in order to gain another person's aid in obtaining objects or events" (p. 658; Bruner & Sherwood, 1983; Seibert, Hogan & Mundy, 1982). Previous research suggested children with autism demonstrated greater deficits in indicating skills than in affiliative or requesting skills.

Method:
Participants: Three groups of children were used in this study: children with autism, children with mental retardation, and typical children. Eighteen children with autism (14 boys and 4 girls) between the ages of 34 to 75 months participated. An additional 18 children with mental retardation (9 diagnosed with Downs Syndrome and 9 diagnosed with unspecified etiologies) also participated as well as 18 typically developing children. All of these children were matched to the chronological or mental age of the individual children with autism.

Procedures/Assessment instruments: Each child was individually assessed across three sessions in a designated room. The first session consisted of a nonverbal social communication measure in addition to either the Cattell Scales of Infant Intelligence or the Stanford-Binet. During the second session, each child was presented with an unstructured play task in addition to the Reynell Language Scales. The third session consisted of a structured play task. Each of these measures was administered by independent testers.

During the first session, nonverbal social communication skills were measured using a form of the Early Social Communication Scales (ESCS, Seibert & Hogan, 1982). In this assessment, the experimenter presented the child with social games and turn-taking opportunities. This session was videotaped and later analyzed for three types of behaviors: social interaction, indicating, and requesting. These three behaviors were further divided into six types including: responding to social interaction, initiating social interaction, responding to indicating, initiating indicating, responding to request, and initiating request.

During the second session, play skills were assessed using both a structured and an unstructured setting. The experimenter modeled four different types of symbolic play while the child sat on his/her mother's lap and watched. After the modeling, the mother and the experimenter sat in opposite corners of the room and observed the child playing with the toys for 16 min. The behaviors the child demonstrated were marked on a checklist. These play behaviors were divided into two categories: functional acts (e.g. brushing the doll's hair) and symbolic acts (e.g. placing a marble on a spoon to feed the doll).

During the third session, these same play skills were assessed in a 30 min structured play session. In these sessions, the experimenter handed the child a specific set of toys while a second experimenter observed and recorded observations.

Conclusions: The children with autism participated in shorter turn-taking sequences, responded less frequently to invitations, used less frequent eye contact, and pointed less frequently to objects out of their reach. These behavioral deficits fell into the category of initiating behaviors.

In addition, children with autism demonstrated difficulty engaging in joint attention behavior (i.e. looking between the toy and an adult) as well as fewer symbolic acts with objects. Mundy, Sigman, Ungerer, and Sherman (1986) concluded that the "disturbance in the development of non-verbal indicating skills is a significant feature of the social skills deficits exhibited by young autistic children" (p. 668).

Relevance to current study: This study compared the types of social engagement behaviors demonstrated by typical children to those demonstrated by children with autism.

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

Purpose of the study: Pierno et al. studied interactions of children with autism and robots, with emphasis on imitation of the robot. Research has shown that children with autism are impaired in imitation abilities. There are two types of imitation: imitation via verbal instruction and automatic imitation (i.e., the individual imitates the actions without being prompted). This particular research study focused on automatic imitation.

Method:
Participants: Researchers compared 12 high-functioning children with autism (ages 10-13 years old) with 12 controls (i.e., typically developing children matched for sex and age).

Procedure/Assessment Instrumentation: Each individual participated in a block of 20 trials for four different conditions. These conditions were named the following: 1) Human-human condition, 2) Robot-human condition, 3) Human control condition, and 4) Robot control condition. During the human-human condition, a model and a child were seated at a table facing each other. A start signal sounded and the model would "preform a reach-to-grasp action towards the target stimulus" (p. 449) (i.e., a spherical object). After the model completed the action, a second signal would sound which indicated the child was to perform the same action towards the spherical object. The child was instructed to perform a reach-to-grasp action when the sound was presented, but was not explicitly instructed to imitate the model. The robot-human condition was identical to the first except the model was a robot arm instead of a human. During the human control condition, the child performed the reach-to-grasp action "in the presence of the static human model" (p. 450). The robot control condition was similar to the third except the child performed the action in the presence of the static robot model.

The ELITE motion analysis system recorded arm movements and a video camera recorded eye movements. Movement duration and the time of maximum grip were analyzed using ANOVA (i.e., a repeated-measures analysis of variance).

Results: The results from this study showed that "facilitation effects were evident only in the 'human' condition for the normally developing children and only in the 'robot' condition for the children with autism" (p. 451).

Conclusions: These results were consistent with previous studies. Pierno et al. raised the question "…why would children with autism be facilitated by a robot prime?" (p. 452). They speculated children with autism may be able to detect the slight variance in human movements (even if they are performing the same action every time) and may not be able to cope with this variance. Whereas robot actions are highly predictable and do not demonstrate this slight variance. This finding suggested that the use of robots may elicit automatic imitative actions in children with autism.

Relevance to the current work: This article compared the ability of children with autism to imitate the actions of a robot and a human model.

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

Purpose of the work: There has been an increase in the prevalence of childhood disorders related to the autism spectrum. Prelock and Contompasis explained that in order to better understand these disorders, it is important to understand the characteristics of the disorder.

Summary: This work discussed trends in the diagnosis of ASD and described different pervasive developmental disorders. Diagnostic assessment tools for ASD are also discussed. Second, the work described early indicators of ASD in addition to the best practice guidelines for arriving at a diagnosis. Third, the work described the role of practitioners in diagnosing ASD. Fourth, Prelock and Contompasis discussed differential diagnoses of ASD with the following disabilities: specific language impairment, learning disabilities, mental retardation, obsessive-compulsive disorder, attention-deficit/hyperactivity disorder, personality disorders, and schizophrenia. Finally, the authors discussed neurobiologic considerations including anatomical abnormalities, brain-behavior findings, and speculated etiology.

Conclusions: This chapter presented characteristics of disorders on the autism spectrum and compared them with other developmental disorders.

Relevance to the current work: This work addressed trends in the diagnosis of ASD as well as early indicators of ASD.

Prelock, P. A., & Ducker, A. (2006). Understanding and assessing the social-emotional development of children with ASD. In P. Prelock (Ed.), *Autism Spectrum Disorders: Issues in assessment and intervention* (pp. 251-301). Austin: Pro-Ed.

Purpose of the work: Prelock and Ducker explained different aspects of the social-emotional development of children with ASD and the process of assessing areas of deficit. This work also discussed the differences in social-emotional development between typically developing children, children with other developmental disabilities, and children with ASD.

Summary: Prelock and Ducker described the social-emotional development in typically developing children as well as differences in the social-emotional development in children with

ASD. Children with ASD typically manifest deficits in the following areas: joint attention, face perception and emotion recognition, gesture and imitation, theory of mind, and executive function. These deficits have a negative impact on arousal and attention. The authors presented a process for creating a profile of social-emotional development, emotional development and behavior. Prizant and Wetherby (1990) described social-emotional development as the child's ability to "experience and express a variety of emotional states, to regulate emotional arousal, to establish secure and positive relationships, and to develop a sense of self as distinct from others." Areas of emotional development and behavior include self-regulation, forming relationships, two-way communication, complex communication, emotional ideas, and emotional thinking. Prelock and Ducker presented a framework for a social-emotional assessment.

Conclusions: One of the major characteristics of children with ASD is the difference in social-emotional development, especially in social interactions. Because of these deficits in social-emotional development, it is difficult for a child with ASD to "engage in meaningful and sustaining social relationships" (p. 288). Prelock and Ducker recognized and evaluated these areas of social-emotional development.

Relevance to the current work: This work addressed joint attention deficits in children with Autism.

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

Purpose of the work: Rapin discusses the clinical features and characteristics of autism.

Summary: There is no specific, single disease or etiology directly correlated with autism; however, a small fraction of individuals diagnosed with autism do have a known etiology (e.g., fragile X chromosome abnormality and congenital rubella). Because autism is a behavioral disorder, much of the criteria for diagnosis is behavioral as well. Autism is categorized as a pervasive developmental disorder (PDD). According to the *Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R)* there are three criteria necessary for a behavioral disorder to be classified as autism. These include the following: (1) "qualitative impairment in reciprocal social interaction, (2) qualitative impairment of verbal and nonverbal communication and imaginative activity, and (3) a markedly restricted repertoire of activities and interests" (p. 752). Individuals with autism often are not aware of emotions and the impact of actions on others. These individuals do not recognize facial expressions and prosody accurately. Consequently, these individuals have a difficult time with social interactions and relationships. Children with autism exhibit deficits in the following areas: maintaining the topic, turn-taking, and joint attention. Children with autism have the tendency to be attracted to consistency and repetition, however, not all individuals with autism act in the same manner or share the same emotions (i.e., some are always happy while others are always unhappy or constantly throwing temper tantrums). In addition, individuals with autism vary in the amount of attending he/she exhibits (i.e., some are highly distractible while others have long attention spans for specific activities).

When assessing a preschool child, there are two major categories of "differential diagnoses" (p. 756): 1) autism and mental deficiency (in lower-functioning children) and 2) autism and developmental language disorders (in higher-functioning children). Once a diagnosis is determined, a management program is created; however, because of how little is known about the pathophysiology of autism, management focuses on reducing symptoms associated with autism. Rapin believes “the cornerstone of the management of autism is special education” (p. 758).

Conclusions: Autism is a disorder that affects the brain’s functioning and is manifest in deficits in maintaining the topic, turn-taking, and joint attention. The degree of impact the disorder has on the social development and the intelligence of a child depends on the severity of the disorder. The severity can range from the child being completely nonverbal (i.e. total lack of language) to being verbal (typically through echolalic speech).

Autism is becoming more prevalent in society, especially amongst boys. It makes itself manifest in the early preschool years; however, the cause for the disorder is still unknown. There is no cure or specific medication for the disorder, but there are medications that can help decrease the severity of some of the symptoms (e.g., seizures and attention disorders). An individual diagnosed with autism can improve social skills and communicative abilities, but the amount of improvement is dependent upon the severity of the disorder.

Relevance to the current work: This work describes characteristics of autism and how to diagnose the disorder.

Ray, C., Mondada, F., & Siegwart, R. (2008, September). What do people expect from robots? Paper presented at the IEEE/RSJ International Conference on Intelligent Robots and Systems, Nice. 3816-3821.

Purpose of the study: Ray, Mondada, and Siegwart explored the population’s attitudes toward robots (both positive and negative) as well as preferences for the technology (e.g., appearance and interaction modalities). Research indicated an increasing trend in the use of robotics in daily personal life. Because of this trend, there is a need for the technology to be accepted by the general population in order for it to be successful. Previous studies on this topic were smaller in scope or had a more specific focus. This study used a larger sample of the population and a broader focus, so results can be added to previous studies.

Method:
Participants: The researchers attempted to create a questionnaire with the most minimal amount of bias through an initial open-ended interview of 11 individuals. The questionnaire was created based on results. These questionnaires were then distributed to visitors at the Geneva Fair. There were a total of 240 questionnaires completed.

Procedures/Assessment Instrumentation: In order to more fully understand how people perceive robots, four question topics were taken into account: 1) what the term *robot* means and what do individuals associate with this term; 2) the positive and/or negative aspects; 3) the beliefs of the future development of robots; and 4) any previous influences/contacts with robots. The questionnaire also covered what the robot should be able and/or allowed to do and the overall appearance of the robot.

Results: Results from the questionnaire indicated a large proportion of the sample had a positive perception of robots. Results also indicated the general population felt robots should be limited to household tasks as opposed to tasks that involved some sort of relationship.

Results indicated a very strong opposition to animal-like robots. In addition, "creature and human appearances were also strongly undesirable" (p. 3820). The overall consensus was the robot should have a "small machine-like" appearance (p. 3820).

In part of the questionnaire, participants were asked to choose one of five categories to indicate their preference of interaction modalities. The most popular choice was to communicate with the robot through speech.

Conclusions: In conclusion, the study indicated an overall positive attitude towards robots. The researchers hypothesized that negative perceptions of robots may be attributed to the influence of the media. Although the questionnaire showed this fact, the participants expressed the idea that robots should not replace "humans when other living beings are involved" (p. 3820). In addition, the robot should not be humanoid in appearance or creature-like. Instead, the robot should resemble a small machine.

Relevance to the current work: This article discussed the characteristics of robot interfaces accepted by users.

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

Purpose of the work: Ricks developed a robot for use in clinical intervention for children with autism. In creating a robot, Ricks hoped it will "lead to therapeutic benefits that may not be achieved without the presence of the robot" (i).

Method:
Participants: Three clinical trials with Troy were completed. The first consisted of two typically developing children (a female age 3 and a male age 4). The second consisted of a 4:7 male with developmental and behavioral handicaps but not autism. The third consisted of an 8 year old male with autism who demonstrated deficits in joint attention and social engagement behaviors.

Procedures/Assessment Instrumentation: Each child participated in a triadic interaction with the robot, a graduate clinician, and an assisting graduate clinician while sitting at a table or on the floor. Troy, the robot, was placed in the middle of the room. Troy had been programmed with actions to help engage the child, such as pushing a ball or tapping a tambourine, as well as changing facial expressions. The child with autism also had a familiarization stage, where the robot was introduced to the child but then left alone for 40 min of the therapy session. The robot was then included in the interactions for the remaining 10 min of the session.

Results: Both typical children engaged with the clinicians and the robot. The handicapped child was initially hesitant with Troy, but later became more eager to interact with the robot. The handicapped child displayed positive affect while engaged with Troy and the clinicians, thus showing his interest in the interactions. The child with autism initially showed mild interest in Troy. Later, when Troy was included in the interaction, the child was very excited and showed positive affect.

Conclusions: Preliminary trials "suggest[ed] that Troy is an engaging tool that helps the children [became] more interactive during therapy sessions" (i). These trials have also shown that the children were not only intrigued by Troy but also engaged in activities with him.

Relevance to the current work: This work described Troy, the robot used in the current study.

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

Purpose of the study: This study was part of the Aurora project. The Aurora project investigated the possibility of using robotic toys in interventions for children with autism. The project's main focus was on the ability of robots to encourage and facilitate joint attention abilities in an individual with autism.

Robins et al. studied joint attention skills in children with autism and the importance of these skills in development. Research has shown that although there were differences in the severity levels of joint attention deficits, these behaviors were not completely absent.

Computers effectively introduced language, academic, and social skills to children with autism. Virtual reality has provided a safe and predictable environment while helping people with autism practice real-life situations at different complexity levels. Robins et al.'s experiment specifically focused on turn-taking, imitation, and joint-attention skills. The researchers analyzed the initiations and responses of a child with autism during an interaction with a robot.

Method:
Participants: The researchers conducted a longitudinal study involving four children with autism. Children ranged in age from 5-10 years.

Procedures/Assessment Instrumentation: Over a period of several months interactions between a child and a humanoid robot were recorded. The robot was a doll named Robota. The doll had two different physical appearances: a "pretty doll" and a more robotic doll. The robotic doll wore plain clothing and had a featureless head. The robot was programmed to dance to nursery rhymes.

The Conversation Analysis (CA) was used to analyze the data. The CA technique looked at the interactions between individuals, the sequence of these interactions, and the events that followed because of these interactions. The CA technique lacked a control group. The reason behind this was the actions of an individual with autism can be compared to typical children in similar situations (i.e. the control group).

The researchers videotaped the interactions using two stationary cameras. Using individually manned cameras would add extra unfamiliar adults to the room, thus potentially increasing the stress level of the child. During the trials, the investigator (the one controlling the robot) did not initiate interaction with the child, but responded when the child initiated an interaction. The trial lasted as long as the child felt comfortable in the room, but no less than three minutes. Specific instances of joint attention were selected based on the child's communicative competencies. Those videos deemed *highly meaningful* were transcribed and chosen for further analysis.

Results: The results showed that a robot can be used as "a 'social mediator', an object and focus of attention and joint attention, that children with autism use to communicate with other people" (p. 188). The children in this study demonstrated joint attention skills where the robot was the common medium between the child and the adult; however, it was difficult to determine whether or not the behavior could be attributed specifically to the robot.

Conclusions: The researchers concluded that robots can be used to provide a focus of joint attention that is enjoyable. The researchers concluded that the examples of interactions they studied demonstrated how human interactions can help provide "meaning and significance to otherwise mechanical interactions (with a robot)" (p. 190).

Relevance to the current work: This article discussed interactions between a child with autism and a socially assistive robot.

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

Purpose of the study: Scassellati reported information and conclusions based on three years of working with a clinical research group. In particular, this article described how social robots might have an impact not only on treating autism, but also on the way clinicians diagnose and understand autism.

Research has indicated there is increased motivation in children with autism when robots are used in therapy sessions. Because researchers can control the specific behaviors the robot manifests, particular social skills can be taught and identically replicated for individuals with autism; however, it is still unclear what aspects (e.g., physical and behavioral) of the robot are so appealing to this population. Scassellati and a research team created a system specifically designed to detect social interactions via passive sensing (i.e. recording information regarding social responses without actively being involved in the interactions).

Methods:
Procedures/Assessment Instrumentation: Scassellati and his research team created a simple robot named ESRA. This robot was programmed to exhibit different facial expressions in order to test a child's attentiveness and attempt to elicit particular social skills and behaviors from the child. ESRA had no additional features to collect data or detect movement.

One method of obtaining these data was through *passive sensing* (i.e. motion sensors programmed to detect eye gaze, movement of the individuals, and the aspects of prosody produced by the voice). The current system only worked when the toddler was contained in a small area. There were modifications being introduced to enable the system to collect data of a larger area with adolescents. In addition, current methods for measuring prosody were difficult to use in a clinical setting. The newer system Scassellati created is capable of classifying between five classifications of prosody: prohibition, approval, soothing, attentional bids, and neutral utterances. This greatly improved the ability of clinicians to more easily measure prosody during social interactions. A second method of obtaining data from social interactions was through the use of the *interactive social cue measurement*. These data were obtained using an interactive robot.

Results: It was reported that typical children were most often engaged with the robot initially but gradually lost interest. Children with autism had a tendency to attend to the robot whether or not it was initiating or responding to the child.

Conclusions: The use of interactive robots helped facilitate collection of objective and quantitative data during social interactions. Additional extensive research needs to be completed in order to create an interactive robot that will be effective during therapy for a child with autism.

Relevance to current work: This article discussed ways to collect data from interactions between a child with autism and a socially assistive robot.

Scattone, D. (2007). Social skills interventions for children with autism. *Psychology in the Schools, 44*(7), 717-726. doi: 10.1002/pits.20260

Purpose of the work: Scattone reviewed the use of social skills training techniques in interventions for children with autism. Research has shown that individuals with autism often received intervention focusing on teaching preacademic skills. Such interventions helped decrease the academic gap, thus helping the individual to mainstream into classrooms with typical children. Social skills did not improve at the same rate, however. This increased the difference in the level of social skills in that age group. Interventions for targeting social skills included video modeling, priming, self-management, written scripts, Social Stories, and pivotal response training. Scattone described these different intervention techniques and generalization and maintenance of the skills these programs target.

Summary: Scattone emphasized that social skills, as well as language and preacademic skills, should be a main focus of intervention during the child's preschool years, continuing through his/her lifetime. Scattone included guidelines for implementing social skills intervention techniques in therapy. The specific skills Scattone targeted in these guidelines included the following: self-management and video modeling, script fading, Social Story writing, and Pivotal Response Training. Some techniques included Social Stories and written scripts. These techniques were used to teach social skills and were easy to implement in therapy. These methods were also easy to establish in the home of the child. There were more complex techniques such as video modeling and pivotal response training that usually require an expert. One of the more effective techniques was self-management because it encouraged children to monitor their own behavior without cues or help from an adult. This helped promote generalization of techniques, thus increasing self-reliance.

Conclusions: Scattone concluded that although individuals with autism often have deficits in social skills, these skills can improve through social skills intervention. There were many different types of social skills interventions that range in complexity (from Social Stories to video modeling) and have differing levels of effectiveness.

Relevance to the current work: This article discussed social skills interventions for children with autism.

Tanaka, F., Cicourel, A., & Movellan, J. R. (2007). Socialization between toddlers and robots at an early childhood education center. *Proceedings of the National Academy of Sciences of the United States of America, 104*(46), 17954-17958. doi: 10.1073/pnas.0707769104

Purpose of the study: Research has shown that robots can help aid in eliciting social behaviors in children during the first few minutes of interaction. Research has also shown that it is difficult to create a robot that will maintain the children's interest for long periods of time.

Method:
Participants: The study immersed a humanoid robot in a classroom of 18- to 24-month-old toddlers for 45 sessions (roughly 50 min each) across 5 months.

Procedures/Assessment Instruments: The robot was controlled by a human controller. The robot could walk, turn its head, dance, sit down, stand up, lie down, hand gesture, and giggle. When the robot sensed low battery power, it would lie down in a sleeping position. This experiment included 3 phases. During the first phase (lasting 27 sessions), the robot interacted with the children in the classroom using its full behavioral capabilities. During the second phase (lasting 15 sessions), the robot was programmed to interact in a very predictable manner. During the third phase (lasting 3 sessions), the robot was reprogrammed back to its original settings used in phase I.

To evaluate the amount of the interest exhibited by the children during the sessions, fifteen sessions were selected at random. Five UCSD undergraduate students watched the videos and turned a dial based on the quality of the interaction. The students were not informed of the purpose of the study. These results were then averaged for inter-observer reliability. The optimal inter-observer reliability of 0.80 was achieved with a time scale of roughly 5 min. This number suggested the importance of evaluating the quality of the interaction in a time interval of 5 min.

A second analysis involved the tactile interactions between the children and the robot. These interactions included the robot being touched on the arm/hand, leg/foot, trunk, head, and face. The total number of times the robot was touched followed the same tendencies as the quality of interaction scores. The number of tactile interactions increased during phase I, decreased during phase II, and increased during phase III.

Results: Results indicated that the interaction between the robot and the children improved across sessions. During this study, children demonstrated social behaviors toward the robot that led to the progression of the robot being treated more like a peer than a toy. Results also suggested that "touch integrated on the time-scale of a few minutes is a surprisingly effective index of social connectedness" (p. 17958). In addition, robotic technology was "surprisingly close to achieving autonomous bonding and socialization with human toddlers for significant periods of time" (p. 17958).

Conclusions: Tanaka, Cicourel, and Movellan concluded that socially assistive robotics have great potential to enrich the learning experience of children in classrooms. The authors felt that the children established relationships with the robot, thereby increasing the effectiveness of the interactions.

Relevance to the current work: This article discussed the characteristics of robot interfaces that maintained the attention of toddlers.

Tapus, A., Matarić, M. J., & Scassellati, B. (2007). The grand challenges in socially assistive robotics. *IEEE Robotics and Automation Magazine Special Issue on Grand Challenges in Robotics,* 1-7.

Purpose of the work: Tapus et al. reviewed the technology of socially assistive robotics specifically created for individuals with disabilities. Instead of focusing on social interactions, this field of robotics focuses on the physical movements of the robot to socially communicate.

Summary: Robots are able to help improve the quality of life for many different groups of individuals including the elderly, individuals with physical impairments and/or in rehabilitation, and "individuals with cognitive disabilities and developmental and social disorders" (p. 1).

Socially assistive robots can assist the elderly by aiding them with daily activities (e.g., getting dressed, retrieving items, etc.). The use of these robots can help with the space and staff shortages currently being experienced at nursing home facilities by allowing the individual to live more independently (i.e. at home); however, in order to successfully aid the elderly, the robots must have the capacity to be easily commanded through verbal communication. Currently, there are companion robots. These robots are used to fill the role of pets (e.g., cat, dog, etc.) in order to improve the physiological and psychological health of the elderly.

Socially assistive robots can aid individuals with physical disabilities by helping to monitor, motivate, encourage, and even coach rehabilitation. Some of these robots have a more active approach and facilitate some of the rehabilitation exercises by manually helping the patient complete the exercise. Other robots have a more passive approach and motivate and encourage the patient. Research has shown that this motivation, encouragement, and social interaction play a key role in the rehabilitation process, especially for post-stroke patients.

Most of the current research for the use of socially assistive robots for individuals with cognitive disabilities has focused on individuals with Autism Spectrum Disorder (ASD). Individuals with

ASD may need high levels of support for their entire lives and an increase in prevalence increases the need in society for assistance for these individuals. Research studies have reported a "high degree of motivation and engagement in subjects" (p. 3) with disabilities when they interact with robots. The motivation may help with carry over to interactions with humans. In addition, these robots are specifically "designed to detect, measure, and respond to social behavior" (p. 3). The authors contented that these robots can provide quantitative data that is relatively objective and free of observer bias.

There have been challenges to producing an effective socially assistive robot. Tapus et al. divided these challenges into six categories: embodiment, personality, empathy, engagement, adaptation, and transfer. First, the term *embodiment* refers not only to the robot's physical movements, but also to the amount of participation in the interaction (i.e., active or passive). The contributions from the robot bring different levels of meaning to the interactions depending on the amount of participation. Second, research has indicated that "Personality is a key determinant in human social interactions" (p. 3). Researchers have argued whether the robot should have a personality that matches the individual but, there have been very few studies on this subject. Third, research has shown that patients who received empathy from their therapist recovered more quickly than those who did not. This fact emphasizes the importance that the socially assistive robot must be able not only to recognize the communication partner's emotions, but also be able to demonstrate empathy. Fourth, the socially assistive robot must "[establish and maintain]…a collaborative connection between the human user and the robot" (p. 4). The robot must take the initiative in the interaction (p. 4). In addition, the robot needs to communicate verbally as well as nonverbally. Fifth, Tapus et al. emphasized "The robot should be able to learn from the user and adapt its capabilities to the user's personality, moods, and preferences so as to provide a customized interaction" (p. 4). This ability enables the robot to be more engaging in the interactions over longer periods of time (e.g., months and years). Lastly, the skills taught/demonstrated by the robot should be generalized to human interactions. Although generalization has been one of the main goals of therapy, it has been a challenge to achieve.

Further questions and challenges were presented including the following: measuring the effectiveness of the robot and creating robots that are safe and easy to operate.

Conclusions: The study of socially assistive robotics is a relatively new field of research. The robots created can be designed to help a broad range of individuals (i.e., elderly, individuals with cognitive impairments, and physical impairments/rehabilitation).

Relevance to the current work: This article described current technological advances in socially assistive robotics.

Watson, L. R., & Flippin, M. (2008, May). Language outcomes for young children with autism spectrum disorders. *The ASHA Leader*, 8-12.

Purpose of the work: Watson and Flippin reviewed research about children with autism. Watson and Flippin also described language outcomes because early language and verbal abilities predict the level of these abilities later in life.

Summary: Watson and Flippin noted that predicting future levels of language development with children with Autism Spectrum Disorders (ASD) continues to be difficult. These children may not develop language linearly (like typical children). For example, some children with ASD are nonverbal for the first few years of life while others demonstrate echolalia and/or imitation. Both groups of children may have relatively the same language abilities later in life. Reasons children with ASD may have language delays include severe joint attention impairments, severe imitation deficits, and severe appropriate symbolic play difficulties. Additionally, recent studies focusing on improving joint attention have suggested that intervention targeting joint attention is more effective when used in conjunction with an applied behavior analysis (ABA) program. Other modes of intervention included the Picture Exchange Communication System (PECS) and Responsive Teaching/Prelinguistic Milieu Therapy (RT/PMT).

Conclusions: Watson and Flippin concluded that despite the differences in verbal ability, children with ASD need early intervention to facilitate as much development as possible. A general conclusion from the studies was that children need direct instruction in areas of joint attention, imitation, and symbolic play. Research showed that effective interventions are dependent upon the intervention goal(s) as well as the characteristics of the individual who receives the intervention. Parents need to be involved in the intervention process to help the SLP implement the best program possible and to increase the likelihood of generalization of social skills. Early intervention for children with ASD needs to target joint attention, imitation, and play abilities.

Relevance to the current work: This article described the characteristics and intervention needs of children with ASD.

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

Purpose of the work: Westby explained the characteristics of language and communicative competence as well as factors that influence development (i.e. child characteristics, disabilities, and environment).

Summary: According to Westby, *theory of mind (ToM)* is the idea that children begin to recognize that others have emotions and experiences that may be different from their own. Theory of mind is an important concept that children learn at young ages. Theory of mind is also related to the idea of *intersubjectivity*, "an interfacing of mind with other persons" (p. 136). According to Westby, *joint attention (JA)* "involves the integration of information about self-experience of an object or event with information about how others experience the same object or event" (p. 137). Joint attention skills are essential to the development of intersubjectivity. Westby describes three categories of joint attention: responding to joint attention (RJA), initiating joint attention (IJA), and initiating behavior requests (IBR). An example of RJA is "[following] the direction of gaze, head turn, and or point gesture of another person" (p. 137). An example of IJA is "seeking interaction with another simply for the sake of sharing an experience" (p. 137). Finally, IBR occurs when the "infant uses eye contact and gestures to initiate attention coordination with another person to elicit aid in obtaining an object or event" (p. 137). According to research, "the majority of children with autism eventually develop RJA and IBR, but they continue to exhibit deficits in IJA" (Mundy, Sigman, & Kasari, 1994, p. 156).

Westby discussed the emergence of language skills in typically developing children. In addition, Westby discussed possible environmental factors that could influence this language development. There are internal factors that may influence the emergence of language skills include deficits in cognitive, syntactic, or semantic aspects of language. These factors prevent the child from participating in communicative interactions, thus inhibiting the emergence of language skills. Specific factors mentioned include the following: blindness, deafness, specific language impairment (SLI), and autism spectrum disorders (ASD). Westby stated that a key aspect of a child with ASD is "the child's inability to enter into joint attention and affective contact with other people" (p. 156). Without this ability to enter social interactions, the child will have difficulty learning joint attention skills and ToM (which are both essential for higher levels of social understanding).

Westby discussed different ways to assess communicative behaviors in children (i.e. formal measures and informal measures as well as interviews). In addition, Westby discussed assessments for determining the level of ToM and emotion understanding exhibited by the child.

Westby stated that "The social competence reflected in RJA and IJA cannot be trained outside of meaningful contexts" (p. 168). She continues "…children must be motivated to engage with others in sharing experiences that will foster RJA and IJA" (p. 168). Additionally, Westby listed several different approaches and important aspects to include in social engagement intervention.

Conclusions: The emergence of social engaging behaviors (i.e. IJA, RJA, and IBR) is essential to the typically developing child. There are factors that inhibit the acquisition of these skills (e.g. environment, cognitive ability, etc.). Children with ASD typically exhibit a deficit in IJA behaviors. Deficits in these areas of language greatly impact the child's social development as well as other aspects of the child's life. It is important to target these emerging behaviors in language intervention.

Relevance to the current work: This work described how typical children develop social behaviors. In addition, the article described the definitions of joint attention (including the three categories: IJA, RJA, and IBR).

Wing, L., & Potter, D. (2009). The epidemiology of Autism Spectrum Disorders: Is the prevalence rising? In S. Goldstein, J. Naglieri, & S. Ozonoff (Eds.), *Assessment of Autism Spectrum Disorders* (pp. 18-54). New York: The Guilford Press.

Purpose of the work: This chapter discussed possible explanations for the apparent increase in the incidence and prevalence of autism. Reasons included changes in the diagnostic criteria as well as an increase in awareness of ASD.

Summary: Autism is a disorder characterized by "severe impairment of social interaction and communication and by intense resistance to change" (p. 19). The very first studies of autism (in

1943) reported that this disorder was rare; however, in the 1980s and 1990s this idea was challenged. Wing and Potter first discussed and then defined incidence and prevalence.

Second, the authors discussed possible reasons for an increase in the incidence and prevalence of autism. These reasons included: changes in diagnostic criteria (e.g. change in terminology), differences in the methods used in the studies (e.g. target population size), increase in the awareness of ASD, recognition that ASD can be associated with other disorders (e.g. mental retardation, psychiatric conditions, etc.), and the development of specialist services.

Third, Wing and Potter discussed possible explanations for an actual increase in the prevalence of ASD. These explanations included: genetic factors, medical conditions, environmental factors, the MMR vaccine, and migration and ethnicity. The authors noted that some of these factors may have been influential in the increase in ASD but that the degree of influence has not been determined.

Fourth, the authors discussed whether or not there really has been an increase in the number of children with ASD. They discussed studies that focused specifically on this topic; however, the authors cautioned against the validity of these numbers because they were reported on children who were tested/studied before the 1980s (when the rising trend in numbers began).

Conclusions: The authors concluded that the main contributing factors to the rise in ASD are due to the widening of the diagnostic criteria and to an increase in awareness and recognition of ASD. They noted that the question still remains as to whether there has been an actual increase in the incidence and prevalence of ASD.

Relevance to the current work: This chapter described the increased prevalence and incidence of ASD.

Appendix B

Example of an Interaction with Troy

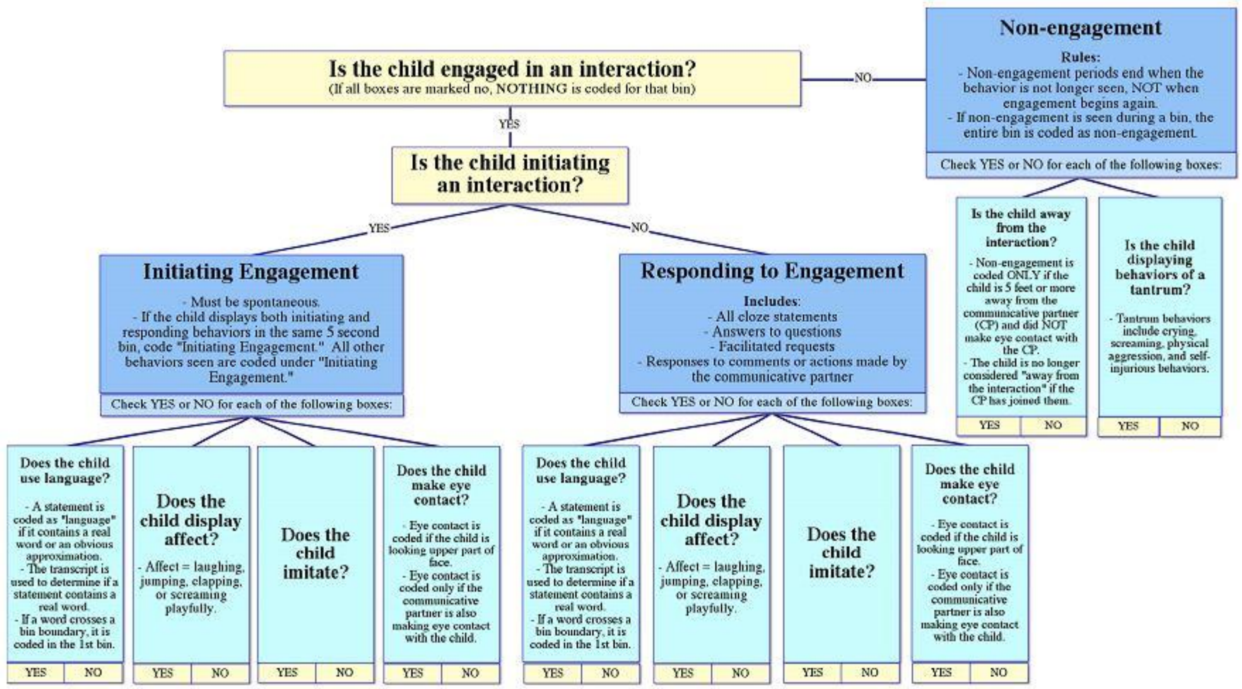
This specific example describes an interaction while playing and turn-taking with a ball.

1. The clinician performed an action (such as rolling a ball to the child) and reacted with positive affect.
2. The robot repeated this gesture and reacted positively with sound or motion.
3. The clinician responded to the robot by using positive comments such as “Wow!” or “Good job, Troy!”
4. The child is invited to imitate the same gesture with a verbal prompt such as, “You do it” or “Pass the ball to Troy.” The assisting clinician helped with hand-over-hand support as needed to perform the action.
5. When the child completed the action, the robot (and often the clinician as well) reacted positively with sound or motion.
6. If the robot did not complete the action correctly, (such as missing the ball) the clinician and the robot reacted with negative affect by saying something like “Oops, try again, Troy.”
7. If the child did not complete the action demonstrated, the robot and clinician reacted with encouragement (e.g. “Almost”) as opposed to negative affect.

(For additional examples of interactions, see Acerson, 2011; Hansen, 2011).

Appendix C

Coding Procedure



Additional Coding Procedures (Acerson, 2011; Hansen, 2011):

- If the child was out of the room during any part of the time scan: non-engagement.
- If the child demonstrates *non-engagement* behaviors during any part of the 5 s interval, the entire interval is coded as *non-engagement.*
- *Initiating engagement* trumps everything (i.e. everything else coded during that 5 s interval is marked as *initiating engagement*).
- Eye contact is established when the child is looking at the upper half of the face *and* the communication partner is looking back.
- If a word overlaps between two 5 s intervals, then it is marked only in the interval it was initiated in.
- Affect includes actions such as laughing, jumping, clapping, or a playful scream.

- The child is no longer away from the interaction as soon as the adult joins him (within 5 feet of the child).
- The child is considered to be non-engaged if they are not at the interaction, even if they are returning to the interaction; however, it is not considered *non-engagement* if they are making eye contact while they are away from the interaction.
- *Non-engagement* periods end when the behaviors are no longer present, *not* when engagement begins again.
- To be considered *language* the verbalization must be a word or an obvious approximation.
- *Initiating* is spontaneous and not in response to something the clinician did. For example, if the clinician asked the child a question, the child's response would be recorded as *responding*. If the child spontaneously makes a request, the child's verbalization is coded as *initiating* behaviors.