The Effect of Intervention Using a Robot on the Social Engagement Behaviors of Four Children with Autism in Interaction with an Unfamiliar Adult

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The Effect of Intervention Using a Robot on the Social Engagement Behaviors
of Four Children with Autism in Interaction with
an Unfamiliar Adult

Sarai S. Dodge

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

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ABSTRACT

The Effect of Intervention Using a Robot on the Social Engagement Behaviors of Four Children with Autism in Interaction with an Unfamiliar Adult

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Master of Science

This study examined the effect of low doses of interactive therapy with a robot on the basic social engagement skills of four children with autism in interaction with an unfamiliar adult. The current study was part of a larger work investigating the effects of treatment incorporating a robot on the social engagement behaviors of children with autism. A single-subject, multiple-baseline research design was implemented and included four types of sessions: baseline, traditional intervention, intervention including the robot, and follow-up. Each participant received a total of 20 intervention sessions in addition to baseline and follow-up sessions. Intervention with the robot was conducted during 10 minutes of 50-minute therapy sessions. The remaining 40 minutes were spent providing highly interactive, play-based therapy similar to that conducted in traditional treatment sessions. Pre- and post-intervention measures of social engagement behaviors were taken and compared. Results indicated that most social engagement behaviors measured remained relatively constant or decreased over the course of the study. Reciprocal and collaborative actions in the context of turn-taking and singing activities, however, increased in three of the four participants. Implications of these results are discussed and suggestions for further research are offered.

Keywords: autism, intervention, robot, social engagement
ACKNOWLEDGEMENTS

Although my name appears as the author of this thesis, this work would not have been possible without the close mentoring and support of my thesis chair, Dr. Brinton. I would also like to thank my other committee members, Dr. Fujiki and Dr. Goodrich, for their willingness to sacrifice and support my work. Similarly, I wish to thank the other “robot girls”: Cambrie Roueche, Kristi Blanchard, and Alyssa Stabenow, without whom I would not have survived. Seriously. Thanks are also due to Ms. Robinson, who kept us all “regulated” during the data collection phase of this experiment via chocolate and calming advice. My love and thanks go to all of my cohort members. We truly are a “band of warriors” – and a fun one at that! I thank my mom, Sally Jackson, for listening to me on all of those phone calls and for being my constant support. To the rest of my family and friends I also extend my appreciation for their contributions to my education.
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Description of Structure and Content

This thesis is presented in a hybrid format which blends traditional thesis format with journal publication requirements. The introduction reflects traditional thesis requirements while the methods, results, and discussion are accordant with current standards for publication in peer-reviewed journals in communication disorders. Appendix A is a copy of the coding manual used to analyze data utilized in the study. Appendix B contains an annotated bibliography.
Introduction

Children with autism exhibit difficulties in social engagement and joint attention (American Psychological Association, 2000). While most traditional interventions directly facilitate interactions between children with autism and other humans, recent investigations have explored utilizing robots in the therapeutic process. The following literature review will explore the nature of autism, the importance of social engagement and joint attention, and the recent research regarding how the use of robots in therapy with children with autism may facilitate improved social interaction.

Nature of Autism

In recent years, the prevalence of autism spectrum disorders (ASD) has been on the rise (U.S. Department of Health and Human Services, 2012). It is estimated that 1 in 88 children in the United States has ASD (U.S Department of Health and Human Services, 2012). ASD is a designation used to describe a range of disabilities including autistic disorder (often referred to as autism), Rett’s disorder, childhood disintegrative disorder, Asperger’s disorder, and pervasive developmental disorder not otherwise specified (American Psychological Association, 2000). ASDs are characterized by “pervasive impairments” in “reciprocal social interaction skills, communication skills, and the presence of stereotyped behavior, interests, and activities” (American Psychological Association, 2000, p. 69).

Children with autism, a subcategory of ASD, display a wide variety of behaviors and deficits that affect many areas of development (American Psychological Association, 2000; Goolsby & Blackwell, 2001; Hughes, 2009; Paul, 2007; Rapin, 1991; Raznahan & Bolton, 2008). Individuals identified with autism meet criteria listed in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR; American
Psychological Association, 2000). Individuals identified with autism demonstrate at least six characteristics listed in three categories with at least two deficits in social interaction, at least one deficit in communication and at least one deficit in interests/behaviors. Social abnormalities include difficulties with non-verbal communication behaviors and shared emotion, difficulties with peer relationships, and a paucity of initiating social interaction with others. Communication impairments may include language delay, difficulty “to initiate or sustain a conversation with others” (p. 75), odd language patterns if/when language develops, and abnormalities in or lack of pretend play. Stereotypic, restricted, and/or repetitive interests and behaviors include such things as unusual fixation on topics of interest, strict following of unusual routines, abnormal intense interest in parts of items, and “stereotyped and repetitive motor mannerisms” (p. 75). Deficits must be present prior to 3 years of age and may also include impairments or abnormalities in symbolic play as well (American Psychological Association, 2000).

**Interactive Behaviors in Children with Autism**

A primary concern regarding children with autism is their difficulty in interpersonal interaction. Early occurring social difficulties have developmental consequences for establishing relationships later in life (American Psychological Association, 2000; Sigman & Kasari, 1995; Volkmar, 1987; Westby, 2010). Although as young children, individuals with autism may not display interest in interpersonal connections, they may desire to establish interpersonal relationships as they become older (American Psychological Association, 2000; Müller, Schuler, & Yates, 2008; Volkmar, 1987). Individuals with autism often encounter difficulty navigating the complex, frequently implicit, rules of social interaction, however (American Psychological Association, 2000; Müller et al., 2008; Saldaña et al., 2009; Volkmar, 1987). These interactional difficulties extend into adulthood as individuals with autism seek independent functioning within
a community (Müller et al., 2008; Nordin & Gillberg, 1998; Saldaña et al., 2009; Volkmar, 1987). Additionally, children with social interaction difficulties often struggle with academic performance (Brinton & Fujiki, 2012). As Wimpory, Hobson, Williams, and Nash (2000) aptly noted, these children often display “profound limitations in social engagement” (p. 529).

**Social engagement.** As defined in the current study, social engagement includes “attending to, expressing interest in, and responding to another individual or individuals for the purpose of interpersonal interaction” (TiLAR Team, 2012, p. 1). This is similar to the definition of social interaction provided by Seibert, Hogan, and Mundy (1982): "Social interaction is narrowly defined to refer to behaviors that gain and maintain the attention and interaction of the partner, primarily for playful purposes (i.e., the pleasure of the interaction) or for contact or proximity" (p. 248). Social engagement encompasses a number of behaviors including joint attention, a primary means of socially sharing one’s environment with another. Social engagement also includes behaviors such as sharing of affect, eye contact, imitating the actions of another, gesturing for purposes of communication, commenting, showing, and turn-taking (American Psychological Association, 2000; Colombi et al., 2009; Seibert, Hogan, & Mundy, 1982; Volkmar, 1987; Westby, 2010).

Deficits in social engagement behaviors are some of the most concerning aspects of autism. Kamp-Becker, Ghahreman, Smidt, and Remschmidt (2009) noted that early social functioning of children with autism was predictive of later abilities in social communication (see also Bruinsma, Koegel, & Koegel, 2004; Charman et al., 2003; Mundy et al., 2007; Mundy, Sigman, & Kasari, 1990; Nordin & Gilberg, 1998; Seibert et al., 1982). Children with autism demonstrate difficulty with social engagement behaviors related to joint attention, such as pointing, showing, and coordinating eye gaze, from an early age (Bruinsma et al., 2004; Chiang,
Soong, Lin, & Rogers, 2008; Goolsby & Blackwell, 2001; Osterling & Dawson, 1994). Indeed, many authors (Goolsby & Blackwell, 2001; Hughes, 2009; Roos, McDuffie, Weismer, & Gernsbacker, 2008) cite deficits in joint attention as a key manifestation of social engagement and a primary marker of autism.

**Joint attention.** Joint attention is particularly important in social engagement. *Joint attention* has been defined by Meindl and Cannella-Malone (2011) as “a set of behaviors that serve to enable two individuals to either vocally or non-vocally communicate about, or ‘jointly attend to’, a third entity, object, or event” (p. 1442). Interactional partners recognize and acknowledge input from one another and their shared interest in the object at hand. Thus, in joint attention, communicative partners both establish and recognize a shared focus. In typical development, joint attention begins to emerge between 10 and 12 months of age (Corkum & Moore, 1995) and continues to develop through the second year of life (Mundy et al., 2007). Development of joint attention is foundational to the later development of language (Bruinsma, et al., 2004; Hughes, 2008; Sigman & Kasari, 1995).

Joint attention can be established when a child either responds to a bid from an interactional partner, or initiates a shared focus (Bruinsma, et al., 2004; Mundy et al., 2003). Bruinsma, Koegel, and Koegel (2004) noted that, “Although the literature contains a number of different definitions of joint attention, these can be divided into two types: 1) response to joint attention (RJA), which can be defined as a child’s response to the parent’s point or shift in eye gaze, or 2) initiation of joint attention (IJA), which can be defined as a child’s seeking another’s attention” (p. 169). IJA develops after RJA and is often indicative of early-emerging social communicative intent (Westby, 2010). Children with autism demonstrate deficits in both RJA and IJA (Mundy et al., 1990).


**Intervention Approaches Utilizing Robots**

Several authors have stressed the importance of addressing early social engagement behaviors in interventions with young children with autism (Charman et al., 2003; Gulsrud, Kasari, Freeman, & Paparella, 2007; Jones, 2009; Kasari, Freeman, & Paparella, 2006). While the vast majority of intervention approaches that address the social engagement deficits of children with autism have been designed to be provided by educators, therapists and parents, recently it has been suggested that some children with autism may benefit from intervention conducted by or mediated by robots (Acerson, 2011; Cole, 2007; Dautenhahn, 2003; Dautenhahn & Werry, 2004; Duquette, Michaud, & Mercier, 2008; Feil-Seifer & Mataric, 2009; Giannopulu & Pradel, 2010; Goldsmith & LeBlanc, 2004; Goodrich, Colton, Brinton, & Fujiki, 2011; Hansen, 2011; Kozima, Nakagawa, & Yasuda, 2005; Miyamoto, Lee, Fuji, & Okada, 2005; Pioggia et al., 2005; Pioggia et al., 2007; Robins, Dautenhahn, Te Broekhorst, & Billard, 2005; Robins, Dickerson, Stribling, & Dautenhahn, 2004; Scassellati, 2007). This section will address how robots may simplify and motivate interaction, promote the extension of social engagement and joint attention behaviors to human interaction, and facilitate the development of a social skill set. Preliminary investigation into the generalization of behaviors learned in therapy with robots is also discussed.

**Simplification of and motivation for interaction.** Human interaction may present a unique challenge for children with autism since changes must be processed rapidly, meanings and reactions are unpredictable and subtle, and the rules of interaction are rarely explicit (Brinton & Fujiki, 2012). Accordingly, it has been suggested that robots may provide children with autism less complex, more predictable interactions (Cole, 2007; Duquette et al., 2008; Giannopulu & Pradel, 2010; Goldsmith & LeBlanc, 2004). Furthermore, studies have indicated that, in general,
many children with autism are highly motivated by, and interested in, robots (Dautenhahn & Werry, 2004; Duquette et al., 2008; Giannopulu & Pradel, 2010; Goldsmith & LeBlanc, 2004; Robins et al., 2005). Some children required a period of time to acclimatize to the robot; however, over all, most children with autism displayed interest in interacting with robots (Dautenhahn & Werry, 2004; Feil-Seifer & Mataric, 2009; Giannopulu & Pradel, 2010; Goldsmith & LeBlanc, 2004; Robins et al., 2005; Scassellati, 2007).

Several studies (Dautenhahn, 2003; Dautenhahn & Werry, 2004; Goldsmith & LeBlanc, 2004; Kozima et al., 2005; Pioggia et al., 2007) suggested that robots may elicit different behaviors in children with autism than do human interactional partners. Duquette, Michaud, and Mercier (2008) found that children demonstrated greater amounts of shared attention and affective expressions with the robot than with human mediators. They hypothesized that this was due to the simplicity and predictability of the robot’s facial design. The children demonstrated greater levels of social conventions and body movements with human interaction partners; however, this may have been due to limitations in the robot’s range of movements (Duquette et al., 2008). Pioggia et al. (2007) found that children with autism imitated the facial expressions and head movements of a humanoid robot without prompting, behaviors which were difficult for these participants previously. Parents of some children involved in the study by Kozima et al. (2005) remarked that their children demonstrated previously unobserved facial expressions in the presence of the robot.

**Extension of interactions to humans.** Some children extended their interactions with robots to include social interactions with other humans in a number of studies (Feil-Seifer & Mataric, 2009; Kozima et al., 2005; Robins, et al., 2005; Robins et al., 2004). In longitudinal observation of interactions of children with autism with a small robot, Kozima, Nakagawa, and
Yasuda (2005) observed children using the robot as an object of joint attention with others.

Robins, Dickerson, Stribling, and Dautenhahn (2004) reported encouraging results in case studies of three children with autism. These children began interacting with the robot and then engaged in social behaviors with the experimenter. The transfer of these behaviors to interactions without the robot present was not examined. Similarly, Feil-Seifer and Mataric (2009) noted that the way that children with autism interacted with a parent was related to a robot in the room.

Social interaction behaviors, both toward the robot and toward the parent increased when the robot demonstrated socially responsive behaviors (Feil-Seifer & Mataric, 2009).

**Instruction in a social skill set.** In robot-mediated social interactions, the goal of intervention with a robot is not for the child to develop a “relationship” or “friendship” with the robots, but rather to develop a set of skills which can then be transferred to human interactions (Dautenhahn, 2003; Dautenhahn & Werry, 2004). Dautenhahn (2003) identified three major roles robots could play in the realm of therapeutic social intervention with children with autism: (a) “the robot as a persuasive machine (a therapeutic playmate)”, (b) “the robot as a social mediator”, and (c) “robots as model social agents” (p. 446). The first two roles are of primary interest in the current study and are described below.

When functioning in the role of therapeutic playmate, the role of the robot is to “teach” children with autism basic social skills such as shared attention and turn-taking (Dautenhahn, 2003). In studies which explored this role of robots, the child was allowed to interact with the robot in any manner he/she wished. The robot was designed to respond to interactions initiated by the child. In observations of child interactions with robots in this role, children maintained the interaction presumably because of robot’s responsiveness (Dautenhahn & Werry, 2004; Feil-Seifer & Mataric, 2009).
In the role as a social mediator suggested by Dautenhahn (2003), the robot is not used as an object of social interaction, per se, but rather as a means to facilitate social interaction between children with autism and their peers and/or adults. The primary objective of using the robots in this scenario is to eventually phase them out of interactions as the child develops greater social interactional competence. Preliminary evidence utilizing a social robot in this manner indicated that children did engage in triadic social interactions with the robot and another individual or with the robot as an object of joint attention between the two human interactants (Dautenhahn & Werry, 2004; Robins et al., 2004). In each of these studies, the generalization of social engagement and joint attention behaviors to contexts outside of the experimental context was not established, however (Dautenhahn, 2003; Dautenhahn & Werry, 2004; Giannopulu & Pradel, 2010; Robins et al., 2005; Scassellati, 2007).

**Generalization of robotic to human interactions.** Generalization of learned behaviors is a primary concern in therapeutic intervention. A recent pilot investigation conducted at Brigham Young University sought to address the issues of generalization of engagement with robots to interaction with human partners. The investigators described two case studies that examined the effects of using interactions with a humanoid robot to increase the social engagement behaviors of children with ASD (Acerson, 2011; Goodrich et al., 2011; Hansen, 2011). Both participants demonstrated severe and pervasive difficulties with social engagement and had made minimal progress in interventions specifically targeting these behaviors prior to the study. As a part of the pilot study, the participants received 40 minutes of therapy similar to what they had received previously. The remaining 10 minutes of therapy was spent in triadic or quadratic interactions with the participant, a clinician, a humanoid robot, and the participant’s parent when available. Intervention with the robot focused on using the robot to engage the child
in interactive activities within the group. The researchers theorized that the low dose of therapy with the robot as well as intentionally integrating human-to-robot and human-to-human interactions would facilitate generalization of social engagement to contexts without the robot. While in the room with the robot, the participants participated in highly interactive play and sharing of affect with the clinicians and the robot. Results indicated dramatic increases in social engagement for one child and modest increases in the other child. These increases were noted in human-to-human interactions when the robot was not present (Acerson, 2011; Hansen, 2011). These results suggested that further research was warranted to determine if a similar intervention program would be effective in increasing social engagement in other children with autism.

**Purpose**

This study was part of a larger investigation of the effects of a low-dose, highly interactive intervention incorporating a humanoid robot. The social engagement behaviors of children with autism in a variety of human-to-human contexts were observed prior to and following intervention. The purpose of the current study was to examine the social engagement behaviors that the children produced in response to bids from an unfamiliar adult. The following research question was posed: Did social engagement behaviors including eye contact, language, initiating social engagement, and reciprocal action, increase in four children with autism following intervention?

**Method**

All methods were approved through the BYU IRB prior to the study. The following sections describe the children who participated. Videotape procedures, a description of the humanoid robot, and the details of various session types are also delineated below.
Participants

Four participants were recruited through the BYU Speech and Language Clinic waiting list, local preschools and elementary schools, and through personal communication of collaborative team members. All participants met the following criteria:

(a) Diagnosis of autism through psychological assessment
(b) Severe and pervasive difficulty with social communication with minimal verbal/non-verbal communication skills
(c) Hearing within normal limits as established through audiologic testing at the BYU Speech and Language Clinic
(d) Availability to participate in bi-weekly treatment sessions for the duration of the study.

Informed consent was obtained prior to the study from the participants’ caregivers. Initial intake information was gathered in February and March of 2011. The study was conducted between March and June of 2011. Informational interviews were conducted with participants’ parents to verify information on clinical intake forms and to gather descriptive data regarding the children’s social history and present functioning. Prior to the commencement of the study, all children received a battery of assessments to evaluate current levels of functioning and to establish clinical treatment goals. This battery consisted of an audiologic examination, administration of the Preschool Language Scale, Fourth Edition (PLS-4; Zimmerman, Steiner, & Pond, 2002), and administration of the Westby Playscale (Westby, 2000). The PLS-4 was used to gather criterion-referenced information on two of the participants, as their ages fell outside of the age range of the standardization sample. Participants were also observed during play interactions with graduate clinicians prior to the commencement of the study.
**Participant 1: AH.** At the commencement of the study, AH was a 4:11 (years: months) girl living with her mother and father. English was the primary language spoken in the home. AH did not have any siblings. Both parents were employed outside of the home during the study. AH was enrolled in a developmental preschool specifically designed for children with ASD. She had opportunities to interact with extended family members as well as with children at school and church.

At the time of the study, AH’s communication was characterized by one-word verbal approximation (i.e. [ps] for *please*) and very limited non-word vocalizations. AH’s mother had attempted to teach AH basic signs. While AH demonstrated ability to imitate signs, she did not use them independently for communicative purposes. To express wants and needs, AH either cried or utilized physical manipulation of others without eye contact. AH also demonstrated repetitive motoric patters with her hands (i.e. hand flapping).

AH demonstrated difficulty regulating emotion, particularly when unable to communicate her needs. When disregulated, AH cried and sought tactile input from others. For example, during the interaction with an unfamiliar adult in the initial baseline session, AH became upset because her jacket zipper was broken and she wanted to leave the interaction. She began crying and moved toward the unfamiliar adult and initiated a hug.

During the initial assessment and according to parent report, AH engaged in limited symbolic play in restricted contexts. For example, she rocked baby dolls and covered them with blankets, but did not elaborate these actions into play schemas or pair them with language. AH’s play interactions with adults mirrored her play behaviors with dolls. For instance, during her initial interaction with the research team, she physically manipulated two graduate clinicians to
interact with each other as if they were dolls. AH did not establish eye contact, share affect, or attempt to engage the clinicians in a mutually shared experience.

AH made infrequent eye contact and when she did, much of the time, interaction partners described the gaze as “empty.” She very occasionally displayed positive affect in relation to social engagement, but at other times, she smiled when no external stimulus was evident. Most frequently, AH presented with little affective reaction in contexts where one would be anticipated.

**Participant 2: LS.** LS was a 9:1 boy at the beginning of the study. He lived with his mother and father and 4 older siblings (ages 11, 14, 16, and 18). He was born in Japan and lived there for the first 4.5 years of his life; however, English was the primary language spoken in his home. LS’s father was employed outside the home, and his mother worked within the home as a homemaker at the time of the study. LS was enrolled in a mainstream preschool at age 3; however, he transferred to a developmental preschool designed for children with autism at age 4. He later attended a kindergarten for children with autism. At the time of the study, he was enrolled at a local elementary school in a self-contained classroom for children with autism and severe disabilities. According to parent report, LS enjoyed interactions with his siblings. He had opportunities to interact with other children at church and at his local Cub Scout troupe; however, he rarely participated in social interactions with children outside his family.

LS displayed sensitivity to sounds and textures and engaged in sensory stimulation behaviors involving tactile stimulation and repetitive motoric patterns. LS exhibited difficulty with self-regulation, easily becoming overstimulated. When disregulated, LS manifested self-injurious behaviors and/or aggression toward others. LS’s expressive vocabulary at the time of the study was approximately 150 words. LS’s verbal communication was limited to requests in
the “I want ______, please” form, one to two word intentional utterances, and extensive echolalia. LS used language to request and protest; social functions of language such as showing and commenting were not observed.

The social interactive meaning of LS’s eye gaze was difficult to interpret. Those who interacted with him closely in the study, including his clinician, assisting clinicians, and clinical supervisors, observed that during some interactions, LS’s eye contact indeed indicated engagement in the interaction, while at other times, the interpersonal connection usually created by eye contact was absent.

LS’s positive affect was also challenging to interpret. Frequently, LS’s demonstrations of positive affect (i.e. giggling and laughing) occurred immediately prior to and during periods of extreme disregulation and aggression. These periods of disregulation were difficult to predict as they sometimes occurred immediately after instances of social engagement.

**Participant 3: KR.** KR was an 8:1 girl at the time of the study. She lived with both parents and five siblings (ages 3, 5, 9, 19, and 23). Her father was employed outside the home and her mother worked within the home as a homemaker. All family members and interaction partners spoke English. KR’s early education began at a local developmental preschool designed for children with autism and later continued at various local elementary schools. At the time of the study, she was enrolled in a self-contained classroom for children with autism.

KR’s communication was characterized by extensive unintelligible jargon with prosodic pattern similar to English. KR produced 4-5 recognizable words at the study’s start. KR demonstrated high levels of physical affection (e.g. hugs) and exhibited enjoyment of social interactions via positive affect and intermittent eye contact. The source of KR’s affect was not
consistent, however. Although she sometimes smiled/laughed in relation to social stimuli, her demonstration of positive affect could not always be directly correlated to the actions of others.

Like other participants, KR had difficulty regulating both positive and negative emotion. When disregulated, she demonstrated self-injurious behaviors (i.e. hand biting) as well as throwing objects and yelling. KR engaged in sensory stimulation behaviors including, but not limited to, visual and tactile fixation on items.

**Participant 4: LR.** LR was a 5:5 boy. He lived with his mother and father and 5 siblings (ages 3, 8, 9, 19, and 23). His father was employed outside the home and his mother worked within the home as a homemaker. His family and those he interacted with all spoke English. At the time of the study, LR was enrolled in a local developmental preschool designed for children with autism.

LR demonstrated extensive repetitive motoric behaviors (ex. hand flapping) and sensory stimulation behaviors including auditory stimulation and tactile stimulation. He also frequently fixated on objects. LR very rarely imitated actions of others and had a short attention span for other-directed behaviors. LR exhibited no verbal communication. His vocalizations were limited to generic continuous vowel sounds and isolated, infrequent simple consonant sounds such as [g]. To communicate, LR used physical manipulation of others as well as inconsistent eye contact and affect. Similar to KR, LR made frequent eye contact and displayed positive affect; however the meaning of these actions was difficult to interpret as the precipitating event was often unclear. LR’s eye contact was frequently paired with non-verbal vocalizations and many times with unusual repetitive motoric hand and finger movements.
Procedures

As indicated earlier, the current investigation was part of a larger study that employed a single-subject, multiple baseline design. Each participant took part in four types of sessions: baseline sessions, traditional intervention sessions, intervention sessions including the robot, and follow-up sessions. Each participant completed the same number of baseline as traditional treatment sessions (e.g. the participant receiving three baseline sessions received three traditional treatment sessions, the participant receiving four baseline sessions received four traditional treatment sessions, etc.). Each participant was assigned to 3, 4, 5, or 6 sessions of baseline and traditional treatment. Baseline sessions were conducted first, immediately followed by traditional treatment sessions. At the completion of traditional therapy sessions, treatment sessions including the robot commenced. Each client received a total of 20 treatment sessions, excluding baseline and follow up sessions. At the end of the prescribed number of robot sessions, three follow up sessions were conducted with each of the participants. Within each baseline and follow-up session, each child participated in four interactions, one with a parent, one with a familiar adult, one with two familiar adults, and one with an unfamiliar adult. The sequence of these interactions varied from session to session. A summary of the distribution of therapy sessions each participant received is presented in Table 1. Treatment was conducted in the clinic rooms of the BYU Speech and Language Clinic.

**Videotape procedures.** Each session was recorded using two camera angles. The two camera angles facilitated a more complete picture of the child’s movements and responses during interactions. Treatment rooms were equipped with a stationary clinic camera mounted on a wall and controlled from a central supervisory room. This camera was controlled by undergraduate and graduate clinical assistants instructed to follow the gross movements of the client about the
room. Visualization of both the client and interaction partner(s) was maintained as frequently as possible. The second camera was one of four hand-held cameras used by undergraduate and graduate clinical assistants in order to capture continuous footage of the participant’s face.

Table 1

<table>
<thead>
<tr>
<th>Session type</th>
<th>Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AH</td>
</tr>
<tr>
<td>Baseline</td>
<td>3</td>
</tr>
<tr>
<td>Traditional treatment</td>
<td>3</td>
</tr>
<tr>
<td>Treatment with robot</td>
<td>17</td>
</tr>
<tr>
<td>Follow-up</td>
<td>3</td>
</tr>
</tbody>
</table>

The robot. The robot used in this study, referred to as Troy, was designed by graduate students in the mechanical engineering department of Brigham Young University specifically for use for treatment with children with autism (Ricks, 2010). The following description of the robot is based on Ricks, 2010 (pp. 23-35). Troy, an upper-body humanoid robot, was built to the general dimensions of a 4 year-old child (see Figure 1). Troy weighed 15 lb, was 25 in (63.5 cm) high from the base to the top of his head, had 12 in (30.5 cm) arms, and rested on a 9x11 in (22.9x27.9 cm) base. Each of his arms had 4 degrees of freedom (DOF): 2 DOF in the shoulder to allow for flexion/extension and abduction/adduction and 2 DOF to enable shoulder rotation and elbow flexion/extension. Troy’s head consisted of a 7 in (17.78 cm) LCD monitor encased in a plastic frame mounted on an RC servo motor, which served as Troy’s neck. Head movements were lateral and vertical, mimicking both head nodding and head shaking. Troy’s face was programmed with happy, sad, and neutral expressions to enable him to react with simple, but
appropriate affect during treatment sessions. Basic greetings, songs, and both positive and negative affective expressions (i.e. *Whoops!,* *Yay, Uh-oh,* and *Yeah!*) were prerecorded by a BYU student majoring in Music Dance Theater. Speakers mounted within Troy connected to a laptop via USB port. Thus, Troy’s “voice” projected either from the computer speakers or from his body (Ricks, 2010). Troy was programmed with specific behavior sets to enable him to participate in various turn-taking and play activities. These behavior sets included, but were not limited to waving, tapping with one arm, pushing with one arm, and performing actions while singing songs. Prior to each session, clinicians programmed a Wii™ remote to trigger the behavior sets needed for the activities of that session (Ricks, 2010).

*Figure 1.* Front, side, and back views of Troy. Pictures were reproduced from “Design and Evaluation of a Humanoid Robot for Autism Therapy,” by Daniel Ricks, 2010, Brigham Young University, Provo. Reprinted with permission.

**Baseline and follow-up sessions.** In the current study, specific activities, similar to those included in the abridged Early Social Communication Scales (Mundy et al., 2003), were conducted to assess the participants’ interaction with an unfamiliar adult. Activities were selected based on their propensity to elicit social engagement behaviors including reciprocal turn-taking, language, and eye contact. The order of presentation of activities varied between
sessions. Participants were not restricted to a certain area of the clinic room but were free to roam about the room and respond to stimuli and interactional bids at will. Clinicians attempted to engage the participants through maintaining close proximity and occasionally repeating probes. In each of the interactions with an unfamiliar adult, the adult-initiated activities including rolling a ball, pushing a car, singing two songs (*The Itsy, Bitsy Spider* and *Popcorn Popping*), presenting three mechanical wind-up toys, presenting a baby doll with a blanket, and presenting a baby with toy dishes. During probes involving the ball, car, and wind-up toys, participant behaviors were coded for 20 seconds after the completion of the probe statement (i.e. “Look at this” or “Push to me”), or until the clinician made a verbal bid to change the interaction. Behaviors associated with the baby doll were coded for 20 seconds after the materials (i.e. the doll and blanket/dishes) left the clinician’s hands. Interaction behaviors during the songs were coded from the commencement of the singing until 5 seconds after the singing ended. After introducing an activity with the specified probe, the adult waited to observe the response of the participant to the stimulus. The adult engaged in or repeated the activity only if the participant produced actions appropriate to the activity. For example, if the participant signed or said, “Again,” after the completion of a song, the clinician repeated the song; however, if the participant did not respond, that probe concluded, and the clinician initiated the next probe.

**Traditional treatment sessions.** At the conclusion of the prescribed number of baseline sessions, the participant participated in the same number of traditional treatment sessions. Traditional treatment sessions were defined as those similar to what a child would receive at the BYU Speech and Language clinic. Traditional treatment sessions consisted of highly interactive, play-based therapy. Treatment focused on increasing intentional communication through verbalization and/or sign, increasing social engagement, and increasing symbolic play skills.
Treatment including the robot. Robot treatment sessions consisted of approximately 40 minutes of traditional therapy and 10 minutes of treatment with the robot. The time segment with Troy was interspersed either at the beginning, middle, or end of each therapy session through quasi-random selection. The traditional treatment portion of the session was conducted in a clinic room without Troy. The clinicians incorporated Troy into therapy sessions as one of a list of planned activities. At the designated time, the participant and the clinician met the participant’s parent and another graduate clinician in a separate clinic room where Troy was situated. The second clinician served to provide hand-over-hand prompting and regulation assistance for the participants when necessary. Troy rested on the floor next to a counter where the connecting laptop was located. Upon entering the room, the lead clinician discreetly controlled Troy’s vocalizations and actions with a Wii™ remote. This enabled Troy to maintain a humanoid persona with the participants and further facilitated the bridge between robot and human interaction. The participants were seated directly across from Troy with the lead clinician and the parent on either side of the child. The assisting clinician sat behind the participant.

Each interaction with the robot began with an exchange of greetings. The remainder of the time was spent in interactive activities such as taking turns singing songs with actions, rolling balls, pushing cars, playing dress up, and playing with pretend food. Turn-taking usually included Troy; however, if interactions between the participant, clinician, and parent continued without the inclusion of Troy, he remained inactive. Treatment with Troy concluded with all interactants’ saying goodbye.

Data Analysis

Each participant’s levels of social engagement were analyzed during baseline and follow-up sessions. Each session lasted between 40 and 55 minutes, depending on the length of
transitions between probes and on the duration of child responses during probes. As part of the larger study, interactions with familiar adults, unfamiliar adults, and triadic interactions were also analyzed. The focus of the current study was the social engagement behaviors each child produced when interacting with an unfamiliar adult.

Instances of eye contact, initiating joint engagement, and use of signed or spoken language were identified during each of the probes. At the end of the presentation of each probe, the participants had opportunity to continue the interaction through eye contact and language or gesture. Contextually appropriate symbolic play was expected during probes involving the baby. Responding to bids for joint attention was expected during probes involving singing, pushing the ball, and pushing the car.

Baseline and follow up sessions were video recorded and later synced using Final Cut Express: Academic Version 4.0.1 (2002) to enable viewing of both camera angles simultaneously side by side. The collaborative team developed a coding system to quantify participant behaviors in response to the adult’s presenting stimulus materials and activities. For a full description of coding procedures, see TiLAR Team (2012). Four graduate students involved with the greater study coded data. One of the coders with extensive prior coding experience was selected to act as the “expert coder” against whom the other coders’ results were measured. Prior to the commencement of data analysis, interrater agreement of 93% for eye contact, 97% for reciprocal action in the context of turn-taking/singing, 95% for reciprocal action in the context of symbolic play, 99% for initiating engagement, and 100% for language was established between the three coders and the expert coder. After data analysis was completed, a quasi-random selection of 20% of the data were selected and double coded to ensure continued accuracy between coders. Percentage agreement remained high between coders with 95% reliability.
coding eye contact, 97% reliability coding reciprocal action in the context of turn-taking, 93% reliability for reciprocal action in the context of symbolic play, 97% reliability for initiating engagement, and 99% reliability for language.

**Results**

The social engagement behaviors that the four children produced in interaction with an unfamiliar adult were considered before and after intervention. As indicated earlier, specific social engagement behaviors measured included eye contact, responding to interactional bids in the context of symbolic play, responding to interactional bids in turn-taking and singing contexts, initiating joint engagement, and language. Frequency of behaviors was tallied in baseline and follow-up sessions and compared. Frequency data for baseline sessions and follow-up sessions will be discussed as well as clinical impressions. All participants participated in three follow-up sessions.

**Participant 1: AH**

Baseline and follow-up session performance for AH is summarized in the following sections. A brief summary of overall performance is also provided.

**Baseline session performance.** AH participated in three sessions of baseline measurement. She demonstrated eye contact in 28% of probes, with frequency of eye contact increasing slightly over the three sessions. AH displayed an overall frequency of response of 15% in turn-taking/singing interactions, with a variable frequency over the three sessions. AH did not produce any language or initiate any engagement in baseline measures. AH responded to joint attention in the context of symbolic play in 11% of baseline probes overall. Her response to symbolic play bids decreased between the first and second sessions and remained constant between the second and third sessions.
Follow-up session performance. AH demonstrated eye contact in 19% of follow-up probes overall, with a slight decrease in eye contact of 1% from follow-up session 1 to follow-up session 3. She responded to bids for interaction in the context of turn-taking/singing interactions in 3% of probes. The entirety of her responses of this type took place in follow-up session 2. AH did not demonstrate any language during follow-up measurement. AH initiated engagement in 3% of probes in follow-up sessions one and three, with an initiation of engagement total of 2% overall. AH responded to bids for interaction in the context of symbolic play in 15% of bids, with responses of this type decreasing sharply from follow-up session 1 to follow-up session 3.

Summary and clinical impressions. AH demonstrated an overall increase in initiating engagement of 2% and in responding to joint engagement in the context of symbolic play of 3%. She displayed an overall decrease in eye contact of 9% and a decrease in responding to joint engagement in the context of turn-taking and singing of 12%. It should be observed that AH had a limited duration of interest in materials. Her clinician observed that even if she displayed interest in a toy in one session, it did not guarantee she would be interested in the same toy the next session, especially if the toy was used several sessions in a row. It should also be noted, however, that in follow-up sessions, despite the overall decrease in frequency of behaviors in the category of responding to joint engagement in the context of symbolic play, AH’s instances of initiation of engagement were in the context of symbolic play (i.e. she held the baby, then returned it to the clinician to hold and paired the action with eye contact). A summary of AH’s frequency of social engagement behaviors is presented in Table 2.
Table 2

AH’s Frequency (and Percentages) of Social Engagement Behaviors by Category in Pre- and Post-intervention Sessions

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre-intervention sessions</th>
<th>Post-intervention sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Eye contact</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-taking/singing</td>
<td>0/6</td>
<td>3/10</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(30)</td>
</tr>
<tr>
<td>Language</td>
<td>0/19</td>
<td>0/21</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Initiating engagement</td>
<td>0/29</td>
<td>0/32</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Symbolic play</td>
<td>4/18</td>
<td>1/18</td>
</tr>
<tr>
<td></td>
<td>(22)</td>
<td>(6)</td>
</tr>
</tbody>
</table>

Participant 2: LS

Baseline and follow-up session performance for LS is summarized in the following sections. A brief summary of overall performance is also provided.

**Baseline session performance.** LS participated in four sessions of baseline measurement. He demonstrated eye contact in 34% of probes, with frequency of eye contact increasing slightly over all of the baseline sessions. LS displayed an overall frequency of response of 28% in turn-taking/singing interactions, with an overall increase over the four sessions. LS produced language in 1% of probes. The language LS produced in baseline was present in the second session and was echolalic in nature; however, as it related to the subject at hand it was coded in this category. LS did not demonstrate any initiation of engagement in baseline sessions. LS responded to joint attention in the context of symbolic play in 3% of
baseline probes overall. The totality of his response to this type of bid occurred in baseline session 2 with no recorded instances of response in the other baseline sessions.

**Follow-up session performance.** LS demonstrated eye contact in 51% of follow-up probes overall, with an overall increase in eye contact of 25% from follow-up session 1 to follow-up session 3. He responded to bids for interaction in the context of turn-taking/singing interactions in 37% of probes. LS’s responses decreased by 30% from follow-up session 1 to follow-up session 3. LS did not demonstrate any language or initiation of engagement during follow-up measurement. LS responded to bids for interaction in the context of symbolic play in 2% of bids, the totality of which occurred in follow-up session 1.

**Summary and clinical impressions.** LS demonstrated an overall increase of 17% in eye contact and 9% in responding to joint engagement in the context of turn-taking/singing. He demonstrated an overall decrease in language of 1% and in responding to joint engagement in the context of symbolic play of 1%. It was noted in reexamination of follow-up session 3 that LS paired his turn-taking behaviors (i.e. returning the item to the clinician) with eye contact and occasional positive affect. A summary of LS’s frequency of social engagement behaviors is presented in Table 3.

**Participant 3: KR**

Baseline and follow-up session performance for KR is summarized in the following sections. A brief summary of overall performance is also provided.

**Baseline session performance.** KR participated in five sessions of baseline measurement. She demonstrated eye contact in 37% of probes; however, her instances of eye contact were variable and ranged from 16% to 60%. KR displayed an overall frequency of response of 37% in turn-taking/singing interactions, again with a variable frequency between the
sessions, but with an overall increase of 13% between session 1 and session 5. KR did not produce any language during baseline measurement. She initiated engagement in a total of 15% of probes. She again showed inconsistent performance from session to session, but demonstrated an overall increase of 22% between session 1 and session 5. KR responded to joint attention in the context of symbolic play in 3% of baseline probes overall. The entirety of her response to joint attention in the context of symbolic play occurred in baseline session 5.

Table 3

*LS’s Frequency (and Percentages) of Social Engagement Behaviors by Category in Pre- and Post-intervention Sessions*

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre-intervention sessions</th>
<th>Post-intervention sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Eye contact</td>
<td>8/23</td>
<td>5/23</td>
</tr>
<tr>
<td>(35)</td>
<td>(22)</td>
<td>(39)</td>
</tr>
<tr>
<td>Turn-taking/singing</td>
<td>1/10</td>
<td>4/10</td>
</tr>
<tr>
<td>(10)</td>
<td>(40)</td>
<td>(30)</td>
</tr>
<tr>
<td>Language</td>
<td>0/21</td>
<td>1/21</td>
</tr>
<tr>
<td>(0)</td>
<td>(5)</td>
<td>(0)</td>
</tr>
<tr>
<td>Initiating engagement</td>
<td>0/32</td>
<td>0/32</td>
</tr>
<tr>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Symbolic play</td>
<td>0/18</td>
<td>2/18</td>
</tr>
<tr>
<td>(0)</td>
<td>(11)</td>
<td>(0)</td>
</tr>
</tbody>
</table>

**Follow-up session performance.** KR demonstrated eye contact in 31% of follow-up probes overall, with eye contact decreasing by 60% from follow-up session 1 to follow-up session 3. She responded to bids for interaction in the context of turn-taking/singing interactions in 42% of probes. The frequency of her responses varied between sessions, but showed an increase of 3% between follow-up session 1 and follow-up session 3. KR did not demonstrate any language during follow-up measurement. KR initiated engagement in 10% of follow-up
probes, with all of her initiations occurring in follow-up session 2. KR did not respond to bids for interaction in the context of symbolic play during follow-up.

**Summary and clinical impressions.** KR demonstrated an overall increase 6% in responding to joint engagement in the context of turn-taking/singing. She demonstrated an overall decrease in eye contact of 6%, in initiating engagement of 5%, and in responding to joint engagement in the context of symbolic play of 3%. KR’s overall results may have been unduly influenced by the results from the third follow-up session. Upon review of this session, it was noted that in some instances, camera angles did not allow for a view of eye contact between KR and the unfamiliar adult. Additionally, at the end of one of the songs, it appeared that KR made a bid to continue the interaction, but because the adult was not familiar with KR and because of the unintelligibility of KR’s jargon, this bid was not attended to. As the interaction progressed, it appeared that KR lost interest in the task as she consistently threw materials and made a verbal approximation of the request, “Mommy, I want to go.” Furthermore, KR responded prior to the official beginning of some turn-taking probes, which rendered them not codable. In another instance, KR began singing “Popcorn Popping on the Apricot Tree” independently, but this occurred after the probe had ended and was not responded to by the clinician as a bid for interaction. A summary of KR’s frequency of social engagement behaviors is presented in Table 4.

**Participant 4: LR**

Baseline and follow-up session performance for LR is summarized in the following sections. A brief summary of overall performance is also provided.

**Baseline session performance.** LR participated in six sessions of baseline measurement. He demonstrated eye contact in 66% of probes, with frequency of eye contact decreasing by 64%
over the six sessions. LR displayed an overall frequency of response of 10% in turn-taking/singing interactions, with a variable frequency over the six sessions. LR did not produce any language in baseline measurement. LR initiated engagement in a total of 3% of probes overall, with instances of initiation ranging from 0% to 9%. LR responded to joint attention in the context of symbolic play in 7% of baseline probes. His response to symbolic play bids increased from the first to the fifth session by 28%, but then decreased to 0% in the last session.

Table 4

*KR’s Frequency (and Percentages) of Social Engagement Behaviors by Category in Pre- and Post-intervention Sessions*

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre-intervention sessions</th>
<th>Post-intervention sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Eye contact</td>
<td>10/20 (50)</td>
<td>3/19 (16)</td>
</tr>
<tr>
<td>Turn-taking/singing</td>
<td>3/7 (43)</td>
<td>1/6 (17)</td>
</tr>
<tr>
<td>Language</td>
<td>0/18 (0)</td>
<td>0/17 (0)</td>
</tr>
<tr>
<td>Initiating engagement</td>
<td>1/29 (3)</td>
<td>4/28 (14)</td>
</tr>
<tr>
<td>Symbolic play</td>
<td>0/18 (0)</td>
<td>0/18 (0)</td>
</tr>
</tbody>
</table>

**Follow-up session performance.** LR demonstrated eye contact in 49% of follow-up probes overall, with eye contact increasing by 7% between follow-up session 1 and follow-up session 2, but then decreasing by 17% between follow-up session 2 and follow-up session 3. He responded to bids for interaction in the context of turn-taking/singing interactions in 19% of probes. LR did not respond to this type of probe in session 2 and he demonstrated a decrease of 23% between follow-up session 1 and follow-up session 2. LR did not demonstrate any language...
during follow-up measurement. LR initiated engagement in 1% of follow-up probes, with all of these responses contained to follow-up session 1. LR responded to bids for interaction in the context of symbolic play in 6% of bids, with responses of this type all contained in follow-up session 3.

**Summary and clinical impressions.** LR demonstrated an increase of 8% in responding to joint engagement in the context of turn-taking/singing. He demonstrated a decrease of 1% in responding to joint engagement in the context of symbolic play, a decrease of 2% in initiating engagement, and a decrease of 17% in eye contact. Upon examination of the second follow-up session, it was noted that LR’s performance may have been impacted by the order in which the interaction with the unfamiliar adult occurred in the session. This interaction occurred at the end of the session, and LR appeared disinterested in the activities. He engaged in eye contact paired with positive affect with the unfamiliar adult, but did not participate in activities. During his time with the unfamiliar adult, he alternatively wandered about the room vocalizing and engaging in repetitive, stereotyped hand movements and lay on the bean bags. In the third follow-up session, amounts of eye contact were decreased due to unfavorable camera angles. A summary of LR’s frequency of social engagement behaviors is presented in Table 5.

**Discussion**

As part of a larger investigation, the current study considered specific social engagement behaviors produced by children in response to bids from an unfamiliar adult. Each participant in this study demonstrated profound limitations in social engagement skills. Each presented with limited ability to connect meaningfully with those around them as evidenced in the areas of eye gaze, language abilities, reciprocal action, play behaviors, emotion sharing, and joint attention. Additionally, each of the participants experienced challenges with self-regulation. Each of the
four children in this study presented a unique profile of abilities and challenges, and there was considerable variation among the children. In addition, there was also variability in the performance of each child from session to session as each child seemed influenced by internal and external factors.

Table 5

LR’s Frequency (and Percentages) of Social Engagement Behaviors by Category in Pre- and Post-intervention Sessions

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre-intervention sessions</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
<th>Post-intervention sessions</th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Eye contact</td>
<td>19/23 (83%)</td>
<td>16/23 (70%)</td>
<td>20/23 (87%)</td>
<td>18/23 (78%)</td>
<td>13/23 (57%)</td>
<td>4/22 (18%)</td>
<td>90/137 (66%)</td>
<td>10/20 (50%)</td>
<td>13/23 (57%)</td>
<td>9/23 (39%)</td>
<td>32/66 (49%)</td>
</tr>
<tr>
<td>Turn-taking/singing</td>
<td>1/10 (10%)</td>
<td>0/10 (0%)</td>
<td>1/10 (10%)</td>
<td>1/10 (10%)</td>
<td>0/10 (0%)</td>
<td>3/9 (33%)</td>
<td>6/59 (10%)</td>
<td>3/7 (43%)</td>
<td>0/10 (0%)</td>
<td>2/10 (20%)</td>
<td>5/27 (19%)</td>
</tr>
<tr>
<td>Language</td>
<td>0/21 (0%)</td>
<td>0/21 (0%)</td>
<td>0/21 (0%)</td>
<td>0/21 (0%)</td>
<td>0/20 (0%)</td>
<td>0/125 (0%)</td>
<td>0/18 (0%)</td>
<td>0/21 (0%)</td>
<td>0/21 (0%)</td>
<td>0/60 (0%)</td>
<td></td>
</tr>
<tr>
<td>Initiating engagement</td>
<td>2/32 (6%)</td>
<td>0/32 (0%)</td>
<td>0/32 (0%)</td>
<td>0/32 (0%)</td>
<td>3/32 (9%)</td>
<td>1/31 (3%)</td>
<td>6/191 (3%)</td>
<td>1/29 (3%)</td>
<td>0/32 (0%)</td>
<td>0/32 (0%)</td>
<td>1/93 (1%)</td>
</tr>
<tr>
<td>Symbolic play</td>
<td>0/18 (0%)</td>
<td>0/18 (0%)</td>
<td>1/18 (6%)</td>
<td>1/18 (6%)</td>
<td>5/18 (28%)</td>
<td>0/18 (0%)</td>
<td>7/108 (7%)</td>
<td>0/18 (0%)</td>
<td>0/18 (0%)</td>
<td>3/18 (17%)</td>
<td>3/54 (6%)</td>
</tr>
</tbody>
</table>

**Highlights of Probe Results**

Results from individual probes were highly variable, and performance in baseline and follow-up sessions was often inconsistent. Considered as a whole, some areas decreased from pre-intervention measurement to post-intervention measurement. Other areas increased when compared, and some areas showed little change from pre- to post-intervention.

Eye contact decreased from pre-intervention measurement to post-intervention measurement in three of the four participants. This may have been due in part to camera angles.

There were instances when eye contact may have been established but could not be coded.
because the view of the participant’s and the clinician’s heads was insufficient. Assuming that eye contact did, indeed, decrease, it may have been because of diminishing interest in probe activities. Children who had become bored with a toy may have lacked motivation to establish eye contact with the adult. Additionally, it was sometimes difficult to interpret the significance of some behaviors, particularly eye contact. For example, at times, it was not clear if a child used eye contact to socially engage with the adult or if she was simply observing her reflection in the adult’s eyes.

The language that participants produced in response to probes remained fairly stable across the study. All participants involved in this study had low language ability with markedly delayed development over the course of several years prior to the study. Therefore, it was not unexpected to see little change in language performance over such a short period of time. Language was important to monitor, however, considering that it is a primary means of connecting socially.

Initiating engagement behaviors decreased or remained relatively stable in three of the four participants. Most of the probes were designed to facilitate responding to joint engagement rather than initiating joint engagement. Nevertheless, initiating joint engagement is a key component of more sophisticated forms of social engagement (Bruinsma et al., 2004; Seibert et al., 1982) so it was important to account for the possibility of initiation of joint attention in the data collection. Two instances of initiation of joint engagement, described previously, were observed and coded during follow-up interactions of AH with an unfamiliar adult. AH displayed no initiating joint engagement with an unfamiliar adult prior to the study, so these instances were of particular clinical relevance.
Responding to engagement in the context of symbolic play also remained relatively stable or decreased slightly in three of the four participants. All of the participants demonstrated limited abilities in the area of symbolic play prior to the study. It would be unusual to observe increases in symbolic play skills in children with low-functioning autism after this short of a period of time. AH, the one participant who did improve slightly in this area, demonstrated instances of symbolic play in one context (i.e. playing with a baby doll) prior to the study and therefore may have had more foundational skills upon which to build in this area.

Improvements in responding to bids for turn-taking/singing were observed in three of the four participants. Improvements in these participants were modest, but nevertheless important, especially considering the interaction was with an unfamiliar adult. These types of activities, especially reciprocal turn-taking, involve joint attention and represent meaningful interactions with another person. For typically developing children, reciprocal turn-taking and collaborative activities such as throwing a ball back and forth, singing songs, etc. are extremely important in developing both communicative and social behaviors. For the children with autism in this study, any increase in reciprocal or collaborative activity with another person could be considered clinically significant. In addition, it was observed that these children also often established eye contact with their turns in turn-taking activities and while participating in songs during follow-up. These types of interaction could, if they were developed, become an important context in which these children could develop more sophisticated social communication behaviors.

It is interesting to note that intervention sessions with Troy focused on triadic/quadratic interactions that involved reciprocal and collaborative actions. Almost all of the activities performed with Troy involved reciprocal actions of one kind or another. Considered in this light, it is encouraging that some degree of increase in social engagement behaviors would be observed
in these types of interactions following intervention. Perhaps the other behaviors that were observed (eye contact, language, initiation) decreased or showed no change because they were not as directly or clearly highlighted in interventions involving Troy.

**Participant Factors Affecting Performance**

Self-regulation was a key component in the performance of each participant. Self-regulation refers to the ability of an individual to identify his/her own internal state of being and modify that state, if needed, to suit the demands of an external situation (see Prizant, Wetherby, Rubin, & Laurent, 2003). This ability is critical to being able to attend to one’s environment and to process incoming information (Prizant & Meyer, 1993; Prizant et al., 2003). The participants of this study struggled to remain regulated during baseline, intervention, and follow up sessions. For example, LS demonstrated difficulty maintaining a regulated, attentive state as he alternated from calm, occasionally socially engaged states to uncontrolled vocalizations (i.e. giggling/laughing, yelling) and self- or other-injurious behaviors. Similarly, AH spent much of the initial sessions crying and continued to have crying episodes where the cause of her distress was not apparent.

The children’s ability to regulate was undoubtedly related to a number of factors, only some of which were apparent. For example, AH’s clinician noted a marked decrease in interaction and ability to participate on days that AH had come from a long day at school. Similarly, LS demonstrated difficulty regulating during a time when his family routines were disrupted (e.g. his father was out of town). KR and LR were both ill at certain points during the study and their clinicians documented a decrease in their performance during these times. All of the children were less well regulated on days when they were fatigued.
The children’s reactions to several intrinsic factors also influenced participant performance. These factors included health, comfort level, fatigue, and interest in probes. Comfort level, e.g. the child’s familiarity with the clinic, the child’s familiarity with clinicians, and their sensory reactions to stimuli, varied from session to session and may have affected responses to intervention. LR in particular demonstrated distinct sensory reactions to stimuli. For instance, on at least one occasion when clinicians introduced a noise-making toy, he reacted initially by plugging his ears and making a pained expression. His reaction altered, however, when the toy was given to him. Rather than plugging his ears, he rang the toy immediately next to his own ear. Fatigue also could have played a part in participant responses. Clinicians noted altered performance on days when the participants’ parents reported that the participant in question did not sleep well.

The materials, toys, and activities used in the probes seemed to be another factor influencing children’s responses. In order to provide consistent contexts in which to observe the children’s behavior, a specific set of materials and toys was used; however, participant interest in these materials varied. For instance, AH initially displayed interest in the baby doll, but this interest faded quickly. She demonstrated little interest in trucks/cars at any time in the study. LS showed little interest in the baby doll, but enjoyed the musical toys so much so that he fixated on them at times. LR initially showed interest in the probe activities; however, as he progressed through the six set baseline sessions and the three follow-up sessions, his interest in the activities decreased. KR initially showed interest in some of the toys and in later sessions threw them away from the clinician. Increasing disinterest in the toys as sessions progressed could have influenced results.
Observations with Troy

The clinicians involved in the study noted reactions of the participants to Troy which were not specifically recorded in the pre- and post-intervention measures. Similar to observations by other researchers (Dautenhahn & Werry, 2004; Feil-Seifer & Mataric, 2009; Giannopulu & Pradel, 2010; Goldsmith & LeBlanc, 2004; Miyamoto et al., 2005; Robins et al., 2005; Scassellati, 2007) the participants of the current study showed interest in Troy. LS and LR paid marked attention to Troy’s face during sessions. LR behaved toward Troy in a similar manner as he behaved toward people. LS’s mother reported that LS used some of the positive affective terms used by Troy outside the clinical setting. Although the significance of this must be interpreted with some degree of reservation considering LS’s extensive use of echolalia, the fact that he was engaged enough in the interactions with Troy to repeat his utterances at times other than during intervention is worth noting.

Interacting with Troy was effective in helping some of the children regulate. For example, AH had great difficulty remaining regulated. In the session in which Troy was introduced, prior to seeing Troy, AH cried continually and was inattentive to all therapy activities. When the clinician introduced Troy, AH stopped crying and was attentive to the interactions with Troy. Furthermore, she remained attentive and regulated for the remainder of the session, even after Troy had been removed from the interaction. Similarly, LR’s clinician noted that while he was in the room with Troy, he had less of a propensity to wander around the room and was more attentive to the activities taking place.

It was the case, however, that the children’s interest in Troy varied. AH’s interest in Troy waned as the study progressed. This pattern of initial curiosity followed by relatively quick abandonment of interest was not atypical for AH. KR demonstrated initial hesitation in
interacting with Troy, but as she became accustomed to him, her behaviors changed. She began to demonstrated aggressive behaviors toward Troy, much as she did toward other children and adults. She still wanted to participate with Troy in interactions, however.

**Study Limitations and Recommendations for Future Research**

In the current study, participants were unfamiliar with their primary clinicians prior to the baseline measures. In subsequent research, participants involved in the study should have the opportunity to receive interventions without the robot from their primary clinician for a longer period of time prior to the initiation of the baseline probes and intervention. A period of familiarity with participants might help children maintain a more consistent state of regulation throughout the intervention. It might then be possible to interpret changes in behavior with more confidence.

In addition, this study only examined social engagement behaviors elicited by a fairly structured set of probes. The analysis system was designed as a conservative measurement of social engagement, and a relatively narrow set of behaviors were identified. To ensure reliability of analysis, strict adherence to the definitions and categories of the specific social engagement behaviors was emphasized in coding the data. Such strict measurement was necessary due to the unconventional, variable, and often subtle nature of participant behaviors. This system ensured that if a behavior was coded, there was a high degree of confidence that it did indeed occur. It was noted by the clinicians conducting intervention, however, that some of the most meaningful instances of social engagement took place outside of the established probes. For instance, in one probe, LR lost interest and did not respond. Then, after the conclusion of the probe, the clinicians began passing the ball (one of LR’s favorite toys) back and forth between them and LR in an informal triadic interaction. LR almost immediately displayed positive affect, giggled and
laughed, made eye contact, and actively engaged in the turn-taking game. Moments like these represented significant instances of social engagement that were not captured by the current analysis system. It would be useful to develop an ethnographic system that would be sensitive to a wider range of social behaviors that comprise important moments of interaction.

Finally, the current study was conducted over a relatively short period of time (approximately three months). Levy, Kim, and Olive (2006) discovered in a review of the literature regarding interventions in young children with autism that duration of intervention was one of three factors most strongly correlated with positive outcomes. Robins, Dautenhahn, Te Boekhorst, and Billard (2005) conducted a longitudinal investigation of social behaviors of children with autism in with a small humanoid robot and suggested that some of the encouraging pro-social behaviors performed by the children took place because they were able to interact with the robot over an extended period of time. If the current study had taken place over a longer period of time, it is possible that more improvements in social engagement would have been observed. In addition, in future research, it will be important to consider follow-up measurements taken at intervals after intervention with the robot to assess improvement and generalization of social engagement across increasingly greater lengths of time.

Conclusion

The performance of the children in this study was quite variable when the pre-intervention baseline probes were compared with the follow-up probes. For three of the four children, the most promising use of the humanoid robot was in the context of turn-taking sequences. The intervention with the robot highlighted reciprocal and collaborative activities, and modest gains were noted from baseline to follow-up in participation in such activities with an unfamiliar adult when the robot was not longer present. These results are preliminary,
however; further analysis of the whole data set gathered from the larger study may provide additional insight. Further research in the area should include longer periods of intervention without the robot prior to introduction of the robot, a more comprehensive analysis system, an increased length of intervention, and follow-up after longer periods of time to assess generalization.
References


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Appendix A

Coding Manual as Used for Data Analysis

Coding Manual

Definitions

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

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

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

Rules

1. Read the directions before coding.
2. When in doubt, don’t code.
3. Don’t code your own client.
Familiar Adult

Baby with blanket
**Probe begins:** when the materials leave the clinician’s hands
**Probe ends:** 20 seconds after the probe began
- **Eye Contact:**
- **Symbolic play:**
  - Child cuddles, hugs, kisses, or rocks baby with or without blanket,
  - Puts on blanket/wraps up baby,
  - Covers self or clinician
  - Self
  - Toy
  - Clinician
- **Initiating:** Following symbolic play, hands item back to clinician
- **Language:** Signs or speaks about baby or blanket topic

Baby with food
**Probe begins:** when the materials leave the clinician’s hands
**Probe ends:** 20 seconds after the probe began
- **Eye Contact:**
- **Symbolic play:**
  - *Code* Feed baby with bottle or spoon
  - *Code* Feeds self or clinician with bottle or spoon
  - Self
  - Toy
  - Clinician
- **Initiating:** Following symbolic play, hands item back to clinician
- **Code** if feeds self or baby and then feeds clinician
  - *Don’t code* if child feeds clinician and then self or baby
- **Language:** Signs or speaks about baby or food topic

Singing
**Note:** Coding begins at beginning of song and proceeds until 5 seconds post completion of the song
- **Eye Contact:**
- **Reciprocal Action:** Participates with correct actions of song
- **Reciprocal Action:** Singing along with clinician
- **Initiating:** Request repeat of song or begins to sing song again within 5 seconds
Ball
Probe begins: when clinician finishes saying: Push to me
Probe ends: Either 20 seconds after the probe or when a verbal bid is made to change the interaction.
Code: if the ball makes it back in ANY WAY to the clinician
Don’t Code: 1. If the clinician physically takes item away
           2. If the clinician moves significantly to receive the item

Eye Contact: 
Reciprocal Action: Returning ball to clinician
Language: Signs or speaks about ball or about activity topic
Initiating: At conclusion of probe, child says or signs “again” or “more”

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

Eye Contact: 
Reciprocal Action: Returning car to clinician
Language: Signs or speaks about car or about activity topic
Initiating: At conclusion of probe, child says or signs “again” or “more”

Wind-up Toys
Probe begins: when clinician finishes saying: Watch this
Probe ends: Either 20 seconds after the probe or when a verbal bid is made to change the interaction.
Code: If child gives toy to clinician independently
Don’t Code: 1. If child gives toy back to clinician with a verbal prompt or a tactile prompt
           2. If child doesn’t give toy to clinician

Initiating prototypes:
Eye Contact: 
Initiating: Give to clinician independently
Language: signs or speaks about wind-up toys or activity topic

Initiating request: Handing or making available to clinician paired with eye contact OR Handing or making available to clinician paired with language (signs or words)
**Unfamiliar Adult**

**Baby with blanket**

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

- **Eye Contact:**
  - Self
  - Toy
  - Clinician

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

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

- **Language:** Signs or speaks about baby or blanket topic

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**Baby with food**

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

- **Eye Contact:**
  - Self
  - Toy
  - Clinician

- **Symbolic play:**
  - *Code* Feed baby with bottle or spoon
  - *Code* Feeds self or clinician with bottle or spoon

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

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

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**Singing**

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

- **Eye Contact:**

- **Reciprocal Action:** Participates with correct actions of song

- **Reciprocal Action:** Singing along with clinician

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

Ball

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

- **Eye Contact:**
- **Reciprocal Action:** Returning ball to clinician
- **Language:** Signs or speaks about ball or about activity topic
- **Initiating:** At conclusion of probe, child says or signs “again” or “more”

Push car

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

- **Eye Contact:**
- **Reciprocal Action:** Returning car to clinician
- **Language:** Signs or speaks about car or about activity topic
- **Initiating:** At conclusion of probe, child says or signs “again” or “more”

Wind-up Toys

**Probes begins:** when clinician finishes saying: Watch this
**Probes ends:** Either 20 seconds after the probe or when a verbal bid is made to change the interaction.
**Code:** If child gives toy back to clinician independently
**Don’t Code:** 1. If child gives toy back to clinician with a verbal prompt or a tactile prompt
  2. If child doesn’t give toy to clinician

- **Initiating prototypes:**
  - **Eye Contact:**
  - **Initiating:** Give to clinician independently
  - **Language:** signs or speaks about wind-up toys or activity topic

- **Initiating request:** Handing or making available to clinician paired with eye contact OR
  Handing or making available to clinician paired with language (signs or words)
**Triadic Interaction**

**Probe begins:** with first hand-off (First clinician passing toy paired with saying “Give to _____.”)  
**Probe ends:** 1. With ANY clinician taking the toy away from child (for the probe to end the clinician MUST have the toy in hand)  
2. A clinician making a bid to end the interaction (a bid consists of a change of phrasing “Can I have the toy?” etc. aka clinician trying to retrieve the item with some sort of verbal request)  
**Code:** the item INDEPENDENTLY makes it back to the correct clinician

- [ ] Eye Contact:  

- [ ] Reciprocal Action: Returning item to clinician independently

- [ ] Language: Signs or speaks about ball or about activity topic

- [ ] Initiating: At a conclusion of a full probe, child says or signs “again” or “more”
Appendix B

Annotated Bibliography


Purpose

This master’s thesis reported on a portion of a greater pilot study which examined the effects of treatment using a humanoid robot in low doses on the social engagement behaviors of two children with autism spectrum disorder. Data reported in this thesis included those related to the child-parent play interactions and the child-clinician interactions.

Method

Two children with autism spectrum disorders and demonstrated pervasive social interactional deficits were selected to participate in the study. They had each been in the BYU Speech and Language clinic for more than one year and had demonstrated little to no improvement.

The participants were involved in a total of 20 sessions lasting 50 minutes each. Sessions included two pre- and two post-treatment sessions and 16 sessions involving time with the robot. Pre- and post-treatment sessions included play interactions based on those outlined by Kasari, Freeman, and Paparella (2006). Session including the robot consisted of 40 minutes of intervention without the robot and 10 minutes of intervention with the robot. Intervention with the robot emphasized exchanging of appropriate greetings, turn-taking play activities, and songs. All interactions were triadic or quadratic in nature and involved the participant, the main clinician, the robot, and a family member, when available. An assisting clinician was also present to provide hand-over-hand modeling and regulation support for the participant when necessary.

Data were coded using a system modified from that used by Kasari et al. (2006) and included frequency and duration data for initiating and responding to engagement behaviors performed by the child. Instances of tantruming and being away from the interaction were also recorded.

Results and Conclusion

One participant demonstrated variable results, with some areas of improvement. The other participant demonstrated improvement in all areas measured. Additionally, clinical observations indicated that areas not measured may have improved as a result of intervention with the humanoid robot. Further research was recommended.

Relevance to the current work

The current work extended the research reported in this thesis. The methodology of the current work was loosely based on that of this pilot study.

Purpose

This section of the DSM-IV-TR described pervasive developmental disorders which included autistic disorder (i.e. autism), Rett’s disorder, childhood disintegrative disorder, Asperger’s disorder, and pervasive developmental delay not otherwise specified. Diagnostic criteria were given for each of the disorders. The details regarding autistic disorder are described below.

Description

All pervasive developmental disorders included deficits in communication, social interaction, and in interest patterns, with those with these disorders demonstrating restricted and/or stereotyped interests and behaviors. Specifically, those with autistic disorder demonstrated a total of six listed criteria with at least two characteristics listed under social interaction, and one each from communication and “restricted repetitive and stereotyped patterns of behavior, interests, and activities” (p. 75).

Relevance to the current work

All of the participants in the study were diagnosed with autism. This article gave the criteria for diagnosis with this disorder.


Purpose of the study

The purpose of this study was to observe the longitudinal development of joint attention of infants from 6 months of age until 18 months of age. Additionally, the researchers observed the role that adults played in the development of emerging joint attention skills as compared with the role of peers.

Method

The participants consisted of 28 infants divided into two groups of 14 with an equal number of boys and girls in each group. The groups were videotaped at 9, 12, 15, and 18 months of age. Recording sessions included segments of the infants involved in interactions with their mother, with a peer, and alone. In each condition, a set of toys was available for the baby and interactants to play with.

Results and conclusions

Results indicated that the amount of time the infant spent engaged in person to person only interactions decreased with age, and the amount of time spent in coordinated joint attention increased with age. This suggested that person to person only interactions preceded the infant’s ability to coordinate attention to an object and another person. The infants also spent more time in passive and coordinated joint attention with their mothers than they did with their peers. Accordingly, the authors posited that “adults are most likely to foster as they scaffold their infants’ activities during the period of development when new communicative skills are just forming (Bruner, 1975; Kaye, 1982)” (p. 1287). However, they suggested that infants in their second year of life could begin to share their environment with peers. The authors interpreted the
results of this study to mean that communication skills are best developed in the context of social interactions.

Relevance to the current work
This article provided background information regarding the development of joint attention in young children.


Purpose
In this chapter, Brazelton et al. described typical mother-infant interaction patterns observed in research studies. The authors also detailed reactions of typically developing infants to violations of the normal pattern of mother-infant interaction.

Results
Typical interactions between mothers and infants were characterized by reciprocal patterns of attention and inattention, initiation and responding to eye gaze, facial expression, and smooth, rhythmic movement. Infants reacted to mothers who failed to respond to their eye gaze and movement with increased jerky movements, signs of distress, repeated attempts to engage the mother, and finally withdrawal and self-comforting behaviors. Each partner in the interaction modified their behavior in response to the actions of the other. Infant behavior toward objects and people differed very early on, which indicated their ability to recognize the difference between objects and people. Infants were able to regulate their level of arousal in ways specific to each type of stimuli. This enabled them to learn non-social and social information without becoming overwhelmed.

Conclusion
Thus, children were equipped with the ability to begin developing their capacity for social interaction very early in life.

Relevance to the current work
This chapter provided information regarding typical development of social engagement in infants.


Purpose
This chapter detailed the relationship between social and emotional abilities to academic performance. The importance of social and emotional functioning was emphasized and suggestions for incorporating this type of learning into academic settings were provided.

Conclusions
The authors provided a review of evidence which showed that children with various disabilities, as well as some typically developing children struggled with social and emotional competence. Social and emotional competence was important in academic settings because of the relationship it had with motivation to learn, inclusion in learning situations, and literacy development. The authors posited that social and emotional competence can be taught and provided several strategies for teaching these skills.

Relevance to the current work
This chapter provided information regarding the importance of social and emotional competence, particularly in academic settings.


Purpose
The authors reviewed the current literature regarding joint attention of typical children as well as children with autism, and paid particular attention to initiating joint attention behaviors. The authors reviewed literature specific to intentional communication, initiating joint attention behaviors in typically developing children, initiating joint attention behaviors in children with autism, and initiating joint attention behaviors as a predictor for autism.

Conclusions
Joint attention was closely related to the development of intentional communication. Typically developing children used joint attention interactions to regulate their environment and to request things/actions (protoimperatives) as well as for social purposes (protodeclaratives). Overall, children with autism demonstrated decreased instances of eye contact, a key feature in coordinating joint attention. In addition, although children with autism did not always differ in the amount of initiating joint attention, they demonstrated fewer communicative acts for social purposes. The authors suggested a need for further research regarding using joint attention as a predictor of language development; however, the existing research indicated that increased joint attention and language have a reciprocal, interactional relationship. In other words, children with higher levels of joint attention behaviors have greater lexical development and children with earlier vocabulary development initiate more joint attention. The authors stressed the importance of more research into the development of joint attention in children with atypical communication development.

Relevance to the current work
This article provided background knowledge concerning the development of joint attention and language in children with autism.

Purpose

These authors defined the goal of Neuro-Developmental Engineering (NDE), which is to develop new ways to assess and treat neuro-developmental disorders using innovative technologies. They presented three novel assessment tools designed to assess neurodevelopment in infants and young children.

Conclusions

These tools were designed to be light, portable, easy to use and inexpensive in order to facilitate evaluation of neurodevelopment in more naturalistic settings for a greater number of infants and children. Of particular note was the “Audio-Visuo-Vestibular Cap”. This device was designed to track head and eye movement of young children in relation to auditory stimuli in naturalistic environments. This device could provide diagnosticians with the ability to measure the amount and duration of eye contact and responsiveness to auditory input of children. It was suggested that the data collected from this device could aid in diagnosing autism.

Relevance to the current work

This article detailed efforts to assist in the assessment of autism with new technologies, which was similar to the focus and design of the current study, although the current work focused on treatment of autism rather than assessment.


Purpose

This study purposed to examine the communication deficits, mainly in the area of joint attention, of young Taiwanese children with autism.

Method

The final subject pool consisted 90 children, 23 children with autism, 23 children with developmental delay, 22 MA matched, typically developing children, and 22 typically developing children aged 13-15 months. Children were evaluated on nonverbal communication using the abbreviated ESCS (Mundy et al. 1996). Behaviors assessed included “high” and “low” levels of initiating and responding to joint attention, “high” and “low” levels of requesting, initiating and “high” and “low” levels of responding to social interaction (including turn taking and initiating song repetitions). A mean generalizability coefficient of .87 was established to indicate sufficient interrater reliability of coded video data.

Results

The final data indicated that the children with autism displayed deficits primarily in initiating joint attention, especially for “higher” level behaviors. These children differed not only from MA matched controls, but also from typically developing children at a lower MA. In addition to joint attention deficits involving objects, some of the children with autism displayed deficits in simple dyadic interactions, which deficits are not always present in children with autism older than three years of age.
Conclusion
The authors suggested that observing dyadic interactions in very young children with autism could aid in early diagnosis and intervention.

Relevance to the current work
This study provided background regarding the nature and development of communication in children with autism.


Purpose
This article examined the relationship between diagnosis of autism or PDD, joint attention, play behaviors, and imitation abilities in children with autism and later language development and abilities.

Method
Assessment regarding play skills, imitation, and joint attention was conducted with 18 subjects at 20 months of age. Language ability at 42 months was assessed for these subjects.

Results
Results indicated poorer language for children with autism compared with those with PDD. Children with higher levels of responding to joint attention and imitation demonstrated higher levels receptive language.

Conclusion
Children with autism had poorer language outcomes than those with PDD. There was a relationship between early social communication skills and later language development.

Relevance to the current work
This article provided background regarding joint attention and language skills in children with autism.


Purpose
This article reported briefly the design and use of KASPAR, a humanoid robot used to facilitate social learning in children with autism. Other research involving robots and children with autism was also reported.

Conclusions
The creators of these robots believed that the simple, predictable design of the robots would facilitate interaction not only between the children with autism and the robot, but also
between the children with autism and other people. The creators noted that generalization of skills was yet to be seen.

Relevance to the current work
This article provided further information regarding the use of robotics in the treatment of social deficits in children with autism.


**Purpose**
This study examined imitation, joint attention, and understanding of others’ intentions in children with autism.

**Method**
Fifteen children with autism and a control group of 15 children with developmental delays matched for non-verbal development participated in this study. Measures of imitation, responding to joint attention, and understanding intentions of others were compared with ability to cooperate with others.

**Results**
Results indicated that children with autism struggled more with imitation and joint attention tasks than the children with developmental delay. No difference was found on measures of understanding others’ intentions. Joint attention and imitation were more related to cooperation than understanding intentions.

**Conclusion**
The authors concluded that children with autism have potential to develop, with intervention, imitation and joint attention skills.

Relevance to the current work
This study provided background regarding basic social skills of children with autism.


**Purpose**
The authors described two studies which examined the development of visual joint attention in infants and the related implications for social development.

**Studies**
Study one sought to determine the age at which visual joint attention emerged in infant development. This study included 60 infants ranging in age from 6 to 19 months, divided into five age groups. The children were seated in front on an experimenter who moved their eyes and
head in specific ways to see if the child would orient similarly. Infant matching and mismatching of experimenter orientation were both coded. Results indicated that, according to the strict operational definition employed in this study, visual joint attention was reliably established in infants around 12 months of age. The social cues to which the infants attended were primarily related initially to the orientation of the experimenter’s head and then to both the experimenter’s head and eyes, but not eyes alone.

Study two sought to examine further the development of visual joint attention as well as the “possible origins of the joint attention response” (p. 74). Infants included in this study ranged from 6 to 11 months of age, divided into three groups. Infant head turn patterns matching or opposite from an experimenter were measured, similarly to the previous study. In this study; however, a visual target was included which was activated in prescribed ways in relation to the direction of the head turn first of the experimenter and then second if the infant’s head turn matched that of the experimenter. Results indicated that infants did not reliably display visual joint attention reliably independently until 10 months of age. Infants were, however, able to learn to display visual joint attention at around 8 months of age.

Conclusion
The authors concluded that visual joint attention emerged between 10-12 months of age and stated that this age fit closely with the development of other early social behaviors such as protoimperative and protodeclarative gestures and social referencing. Furthermore, the authors observed that infants attended first to head orientation and then attended to both eye and head orientation, which indicated the infants’ emerging understanding of the importance of eye gaze in joint attention. The authors commented on the role of learning as a means for developing joint attention at earlier ages.

Relevance to the current work
This chapter gave background information on the typical development of joint attention in infants.


Purpose
In this paper various applications for socially interactive robots were presented. Dautenhahn identified three major roles robots could play in the realm of therapeutic social intervention with children with autism. These roles, especially the first two, were investigated as a part of the ongoing Aurora project, a project designed to determine the efficacy and explore the application of robots in intervention with children with autism. The roles of a social robot described in this paper were (a) “the robot as a persuasive machine (a therapeutic playmate)” (p. 447), (b) “the robot as a social mediator” (p. 448), and (c) “robots as model social agents” (p. 448).

Description and conclusions
The role of robots as therapeutic playmates was to instruct children with autism in basic social skills such as shared attention and turn taking. The child was allowed to interact with the
The second role of the social robots was as a social mediator. In this scenario, the robot was used not as an object of social interaction itself, per se, but rather a means to facilitate social interaction between children with autism and their peers and/or adults. The primary objective of using the robots in this scenario was to eventually phase them out of the interactions as the child develops greater social interactional competence. The third role of the robot identified by Dautenhahn was as model social agents. In this role, the robots would act in theatrical representations of appropriate social interactions, similar to human actors. The benefits of the robots over humans in this situation were, again, their degree of simplicity compared with humans as well as the potential for the children with autism to interact with the robots as well as to watch them perform in the social scripts. Dautenhahn called for further research, particularly for robots as social mediators.

Relevance to the current work

The current study provided further research into the role of robots as social mediators with children with autism.


Purpose

This article described the rationale behind and provided suggestions for the use of interactive robots in therapy with children with autism. A description of the AURORA project was provided. Preliminary evidence in support of the authors’ hypotheses was described.

Rationale

The authors gave three hypotheses with underpinned their work with children with autism. These hypotheses were that (a) children with autism were interested enough in robots for therapies using them to be useful, (b) basic patterns of interaction could be taught using robots, and (c) the complexity of robots and their interaction capabilities could be incrementally increased in order to expand the social skills of children with autism.

Results and Discussion

Results of several studies related to the AURORA project indicated that children were interested in the robots and responded well toward them. The individuality of performance was discussed. Some children demonstrated increased social behaviors in the presence of the robot. In some instances, the robot facilitated social engagement between children with autism and other people. Information regarding current work in the AURORA project was described. The authors also compared the use of robots with virtual environments. The need for studies investigating generalization of social engagement behaviors was noted.

Conclusion

The authors concluded that intervention using robots with children with autism could be useful and should continue to be investigated. The importance of using the robot as a tool to promote human-human interaction was highlighted.
Relevance to the current work

This study provided support for the investigation of teaching social skills to children with autism using robots.


Purpose

This study investigated the effect of a mobile robot on the social interaction skills of children with autism.

Method

Four children with autism were divided into two groups. One group interacted with a human as a social mediator and the other group interacted with the robot as a social mediator in interaction. Various social skills were examined in interactions with the mediator in 22 sessions spaced over seven weeks.

Results

Results indicated that children demonstrated decreased fixation on inanimate objects in interactions with the robot. Similarly, children who interacted with the robot showed increased eye gaze and closer proximity. Rate of shared conventions and imitation was greater in children interacting with the human mediator.

Conclusion

The authors concluded that the simple and predictable nature of robots could facilitate some social skills in some children with autism.

Relevance to the current work

This study provided support for the investigation of teaching social skills to children with autism using robots.


Purpose

These researchers tested the hypothesis that the social interaction behaviors of children with autism would increase in direct response to robot behaviors immediately related to the behaviors of the child.

Method

They designed a non-humanoid robot which had simple, predictable reactions to input from the child (e.g. the robot blew bubbles and turned when the child pushed a button). Their
idea was for the robot to be a mediator of social interaction in human-robot and human-human interactions rather than to specifically teach social interaction behaviors to the child involved.

Results
   Results indicated that participants responded more to robots which responded to the participants’ input than to robots who acted randomly. In addition, the social interaction behaviors, both toward the robot and with the human interactant, were more frequent with the reactive robot than with the random robot. Future directions of research were proposed.

Relevance to the current work
   Children with autism responded with increased social behaviors toward both humans and robots when interacting with reactive robots. However, the robot in this instance was not humanoid and only had a limited range of reactions. It could not be personalized to the specific child. The current work expanded the ideas presented in this work.


Purpose
   The authors reported on a study which examined the social involvement and free play behaviors of children with autism with a simple mobile robot. The authors hypothesized that children would spend most of the time in the room with the robot engaged in some sort of interaction with the robot.

Method
   Four children with autism participated in one 5-minute play session with a robot, GIPY-1. Eye contact with the robot, touching the robot, controlling the robot, and orientation toward or away from the robot were coded.

Results and Conclusions
   The children spent most of the 5 minutes engaged in activity related to the robot. All participants had similar levels of eye contact with the robot, but differed in all other behaviors measured. The children used a variety of behaviors to play with the robot. The authors concluded that the children were interested in the robot and that robots could be used to facilitate more spontaneous play behaviors in children with autism. They suggested further research and highlighted the importance of investigating the generalization of behaviors.

Relevance to the current work
   This work provided evidence in support of using robots in therapeutic interactions with children with autism.

Purpose

A review of the literature surrounding the use of technology in interventions with children with autism was presented in this article. This review primarily summarized research associated with the Aurora project.

Conclusions

This review revealed that use of robotics allowed for a simpler, more predictable mode of interaction for children with autism. It was theorized that as children become more comfortable, the intensity and complexity of the social interaction environment with robots could be increased. Preliminary research showed that children were interested in interacting with socially responsive robots, even if the reaction of the robots was not entirely predictable. Additionally, robots could be a unifying object to promote shared attention, in addition to more direct facilitation of social engagement behaviors such as turn taking and imitation.

Relevance to the current work

This review provided rationale and potential applications of intervention for children with autism using robots.


Purpose

This paper described the design and rationale for a study conducted using a humanoid robot in low-doses in treatment of children with low-functioning autism.

Conclusions

Since interactions between a child and a robot were not the goal of therapy, the authors described how their robot was used in approximately 20% of therapy time with children with autism. This low-dose of interaction with the robot was posited to facilitate the generalization of social engagement behaviors from interactions with the robot to interactions without the robot present. Results from a pilot study were briefly presented. The results showed encouraging improvements in social behaviors.

Relevance to the current work

This study described the rationale for using low-doses of interaction with a robot in therapy with children with autism.


Purpose

This article contained basic information regarding the characteristics of autism. In addition, guidelines for screening and diagnosing autism were offered to medical practitioners.
Conclusions

Autism occurred frequently in the US: more than 1 in 500 people demonstrate the disorder (although more recent research would indicate the prevalence is even higher). Of developmental disabilities, it was the third most common in the United States. Children with autism typically displayed symptoms prior to 3 years of age with many displaying symptoms as young as 18 months of age. Early indicators of the disorder included decreased orientation to name, eye gaze, joint attention, nonverbal communication, and pretend play, as well as abnormal language development. Some children with autism demonstrated lower IQ, increased/decreased/abnormal sensitivity to sensory stimulation, gross and fine motor deficits, and abnormal motoric patterns. Furthermore, abnormalities in cognitive abilities, such as perspective taking, abstract thinking, and planning, were sometimes present.

Relevance to the current work

This article supplied basic background information regarding the characteristics of autism.


Purpose

This study investigated the generalization of joint attention skills of children with autism after participating in joint attention or symbolic play therapy.

Method

Thirty-five children with autism were randomized into two intervention groups: symbolic play and joint attention. Joint attention probes were administered at three different points in therapy to assess generalization.

Results

Results indicated that joint attention behaviors in response to the probes were greater in the children randomized to the joint attention intervention group.

Conclusion

The authors concluded that interventions focused on teaching joint attention to children with autism are efficacious.

Relevance to the current work

This article provided evidence to support targeting joint attention in therapy with children with autism.

Purpose

This thesis reported on two aspects of a larger pilot study investigating the effects of treatment using a humanoid robot on the social engagement behaviors of two children with autism spectrum disorders.

Method

Two children diagnosed with autism spectrum disorders were selected to participate in the pilot study based on their persistent deficits in social communication. Both children had shown little to no improvement in social communication in spite of consistent therapy addressing this issue for at least one year.

Sessions were recorded from two cameras: a stationary camera mounted to face the robot and a handheld camera held by a university student in such a way as to always capture the facial expression of the child. A set number of assessment sessions, with assessment activities similar to those used in the Early Social Communication Scales (Seibert, Hogan, & Mundy, 1982), were conducted prior to introducing the child to the robot. Following sessions included 40 minutes of play therapy and 10 minutes of therapy conducted with the robot. Therapy with the robot was conducted in triadic or quadratic interactions which included the client, the robot, the primary clinician, and a family member when available. A second graduate clinician was present and positioned behind the child in order to provide prompting and hand-over-hand assistance for the child when necessary. Treatment activities included greetings, turn taking and symbolic play activities (i.e. pushing cars, pretending to eat food), and singing. Interactions included affective reactions to activities from both the clinician and the robot. Treatment outside of the time with the robot was structured to address the individual goals of each child.

The data analysis used in the pilot study involved coding video data in 5 second segments. Behaviors examined included language, affect, imitation, and eye contact. These behaviors were categorized as either initiating engagement or responding to engagement. Tantruming and instances of being away from the interaction were also recorded and analyzed.

Results and Conclusions

Although results were more dramatic and consistent with one of the clients, both children made gains in both initiating and responding social communication behaviors after intervention. The results suggested that using a humanoid robot in low doses during intervention with children with low-functioning autism could result in more instances of social engagement.

Relevance to current work

The current study was a follow-up investigation regarding this subject. Of particular note to the current study were the methods employed in the pilot study.


Purpose

Hughes presented a review of the literature published in 2008 regarding autism.

Description and conclusions
The review addressed topics including, but not limited to etiology, assessment, characteristics, prevalence, neurophysiology, cognitive changes, sensory changes, and treatment. The topic of genes was excluded from the search as the author indicated the large amount of literature regarding this subject warranted its own review.

Relevance to the current work
This review provided summaries of articles which described the characteristics of autism, cognitive changes in autism, and current treatments for autism.


**Purpose**
This paper reported on two studies which examined the possibility of teaching initiating joint attention behaviors to children with autism

**Method**
In study 1, behavioral methods were used to teach two children with autism initiation of joint attention with an adult facilitator in the context of playing with toys and routines. Study 2 involved one of the participants from study 1 and focused on teaching initiating joint attention skills with peers using behavioral methods while playing with toys and in routines.

**Results and Conclusion**
Children in both studies increased in their ability to initiate joint attention according to the preset definitions.

Relevance to the current work
This study provided evidence that children with autism can be taught joint attention skills.


**Purpose**
This study examined the relationship between early indicators of autism and later levels of functioning.

**Method**
A subject pool of 140 persons with high-functioning autism or suspected autism was included in this study. All participants were given the ADI-R and the ADOS. Early presenting symptoms of autism were compared with current levels of functioning.

**Results and Conclusions**
Results indicated that early social interaction skills, communication abilities, and anxious and/or compulsive behavior were related to later functioning in the area of social communication.

Relevance to the current study
This study provided evidence that early difficulties in social functioning affect social functioning later in children with autism.


Purpose
This study examined the efficacy of joint attention and symbolic play interventions in teaching these skills to children with autism.

Method
Fifty-eight children were randomized into one of three intervention groups: joint attention, symbolic play, or a control intervention. Intervention took place for 30 minutes a day for 5-6 weeks. Follow-up measures were taken to assess play and joint attention skills.

Results
Results indicated that joint attention skills improved in children who had received joint attention intervention. Symbolic play skills improved in children who had received symbolic play intervention. Skills generalized from the therapy setting to interactions with the children’s mothers.

Conclusion
Interventions targeting specific skills are effective at teaching those skills to children with autism and can generalize to situations outside of intervention.

Relevance to the current work
This study provided evidence in support of teaching specific social engagement skills to children with autism.


Purpose
This paper described the design and use of a small robot in therapeutic play interactions with children with autism.

Method.
The robot, Keepon, was placed in the toy room of a school for young children with developmental disabilities. Child interactions with Keepon were observed longitudinally and summarized.

Results
Results indicated that children with autism had various reactions toward Keepon, but that some of them demonstrated social behaviors not observed previously. Some children extended their interactions with Keepon to include other individuals, and some of the children’s mode of interaction with Keepon evolved over time.

Conclusion
The authors concluded that Keepon’s simple design aided in the comfort with which the children with autism interacted with him. They concluded that Keepon could be useful in helping children with autism develop social interaction skills.

Relevance to the current work
This study provided evidence that some children with autism demonstrate increased social skills while interacting with robots.


Purpose
This article reviewed the current literature regarding interventions for children with autism. The authors identified several factors which were connected to positive therapy outcomes.

Conclusion
Interventions that were most effective in treating autism were those that involved parents, addressed multiple areas of deficit, such as language, social communication, and behavior management, and were intensive over long periods of time. Other factors which related to positive outcomes noted were difficulty of tasks, interaction with typically developing children, learning trajectory, and early verbal imitation.

Relevance to the current work
This article provided background information regarding the most important characteristics of therapy with children with autism.


Purpose
This article provided a review of the literature regarding interventions to teach initiating joint attention (IJA) and responding to joint attention (RJA) to children with autism.
Conclusions

The authors concluded that while some methods of teaching RJA were effective, others were not. Also, RJA could develop as a byproduct of other interventions, specifically, interventions teaching imitation. IJA did not develop as a byproduct of RJA intervention, which lent support to the idea that RJA and IJA are separate skills to be learned. Social rewards alone proved effective for teaching RJA and IJA to children with autism in two studies. The authors emphasized the need for more research into joint attention interventions with children with autism.

Relevance to the current work

This work provided support for teaching joint attention skills to children with autism in intervention.


Purpose

The purpose of this study was to analyze interactions between children in a special education setting with a small robot as compared with a control setting over the course of several months. The authors were interested in the persistence of the children in actions.

Method

Five children, two males and two females, participated in this study. Sessions with the robot occurred once a month between October and February. Each session lasted between 5 and 10 minutes. A classroom was set up with two “experimental environments” (p. 145). An adult was present in the room to provide assistance when necessary and to observe. The robot was controlled remotely from another room. The control environment contained blocks set up on a table. In the environment with the robot, the robot was positioned on a table. The robot either said phrases to the children or moved objects intentionally.

Results

Of the five participants, two children did not interact with the robot and one of them interacted minimally with the robot. The interactions of the other two children were described. One of the children tried to make the robot perform actions according to his desire. The robot sometimes gave verbal directions, which the child inconsistently followed. Eventually, the child stopped responding to the robot. The second child, who was non-verbal, interacted with the robot increasingly over the sessions and eventually began greeting the robot and bidding it goodbye.

Conclusions
Both children showed persistence in some situations with the robot. The authors noted that the children modified their social behaviors in the presence of the robot. Further research was suggested to investigate the use of robots as social agents in interactions with children with autism.

Relevance to the current work

This article provided background information regarding the use of robots in social interactions with children with autism.


**Purpose**

The purpose of this article was to describe the social challenges of adult individuals with ASD based on self-report. Recommendations for social support were provided by the participants.

**Method**

Eighteen individuals with ASD were interviewed regarding their social challenges and their suggestions for solutions to these challenges.

**Results**

Six common challenges were identified across participants, including (a) feelings of isolation, (b) troubles initiating social connections, (c) communication difficulties, (d) desire for greater closeness and connection with others, (e) a need to meaningfully participate in the community, and (f) desire to improve social skills and self-awareness. Suggestions for improvements included greater environmental supports, assistance with communication, and modes of internal regulation.

**Conclusion**

The authors suggested that this research could influence best practices implemented by those who assist persons with ASD.

Relevance to the current work

This article provided information regarding social difficulties in adults with ASD.


**Purpose**

This study investigated the development of joint attention in young children as well as the relationship of joint attention to language at 24 months of age.

**Method**
This study involved 95 infants observed at 9, 12, 15, 18, and 24 months of age. The ESCS was administered at each of these intervals and data regarding initiating joint attention (IJA), responding to joint attention (RJA), and initiating and responding to behavior regulation (IBR and RBR, respectively) were recorded.

Results and Conclusions
Results indicated that, with the exception of IJA, joint attention behaviors developed in a linear fashion. Patterns of development were consistent across cognitive levels, although ages of demonstration of joint attention differed based on cognitive level. Greater levels of joint attention predicted greater verbal ability at 24 months. Suggestions of study limitations and areas of further research were provided.

Relevance to the current work
This study provided information regarding typical development of joint attention.


**Purpose**
This article provided specific rationale for and specific instructions regarding the abridged early social communication scales (ESCS).

**Background**
This version of the ESCS contained fewer items in order to reduce administration time. In addition, scoring was simplified into “higher” and “lower” level behaviors, frequency of behaviors was emphasized, and behaviors were interpreted to reflect developments in “self regulatory and affective processes” (p. 1) as well as social cognition. The ESCS were designed to measure behaviors typically developed between 8 and 30 months of age; however, the ESCS could also be used to evaluate children whose verbal age was within this interval. Behaviors of interest were categorized into three groups: joint attention behaviors, behavioral requests, and social interaction behaviors. Each of these behaviors was labeled as either initiating or responding. Materials utilized in the administration of the scales included wind-up toys; “hand-operated operated toys, including a balloon” (p. 2); a car; a ball; a book; “a toy comb, hat, and glasses” (p. 2); a plastic jar; and posters. These materials were chosen due to their ability to elicit social engagement in interactions with young children.

**Administration**
Optimal room set up was described. This included the child and experimenter sitting across from each other at a table. The child was allowed to be seated on the parent’s lap, if needed. Directions for administration included the minimal use of verbal communication from the experimenter and parent during probes; yet, the administrator was instructed to be responsive to communication from the child. Parents were instructed to refrain from prompting their children so an accurate measure of the child’s social interaction could be achieved. Specific instructions were given regarding specific probes.
Coding and Scoring

Coding procedures were described. Specific behaviors were classified as higher or lower in the categories of initiating joint attention, responding to joint attention, initiating behavioral requests, responding to behavioral requests, initiating social interaction, and responding to social interaction. Examples of language and “point in imitation” were given. Specifics regarding scoring were provided.

Relevance to the current work

The baseline and follow-up probes used the current study were loosely based on the ESCS. This manual also provided some information regarding joint attention and social engagement.


Purpose

The authors investigated the relationship between joint attention skills and language development in children with autism.

Method

Fifteen children with autism and 15 children with intellectual impairments participated in this study. Participants’ early social communication skills were measured and compared between two sessions 13 months apart.

Results

Children with autism demonstrated significantly less joint attention in both sessions. The deficits in joint attention in the first session were related to poorer language outcomes at the follow-up session.

Conclusion

This study provided further evidence of the joint attention deficit in autism and for the link between joint attention and language development.

Relevance to the current work

This article provided information regarding joint attention skills in children with autism.


Purpose

The authors reviewed the literature regarding the course of autism over the lifespan. Several indicators present in childhood affecting later functional outcomes were discovered.

Conclusion
Several factors in childhood related to future functioning of persons with autism. These included IQ, communication abilities, perspective taking, and flexibility. The authors reported the need for more longitudinal studies on this subject.

Relevance to the current work
This article provided information regarding social difficulties in individuals with ASD.


Purpose of the Study
Osterling and Dawson purposed to provide information about the early behaviors of children who were later diagnosed with ASD as compared to typically developing children through analysis of first birthday home videotapes. Their goal was to provide information which would aid in earlier diagnosis and treatment of the disorder.

Method
Videotapes of the first birthday party of 11 children with ASD and 11 typically developing children were gathered from the subject pool at the University of Washington. Each group contained 10 boys and 1 girl. The videotapes were coded by raters blind to the diagnosis of each child. Coding took place in one-minute intervals to determine the presence or absence of several behaviors, both autistic-like and developmentally appropriate. A developmental pediatrician who specialized in developmental disabilities who was blind to each child’s diagnosis also viewed the videos and rated each child based on clinical judgment.

Results
Children later diagnosed with autism displayed significantly less social and joint attention behaviors than the typically developing children; however, there was no significant difference in communicative behaviors. The children later diagnosed with autism also displayed significantly more autistic behaviors. Children with autism did not orient to their name as frequently as typically developing children. None of the children with autism pointed, which produced a significant difference from the typically developing children. The typically developing children showed objects and looked at others’ faces significantly more than the children with autism. Identification of autism was not influenced by the presence of cognitive delay, although this may have been due to small group size.

Conclusions
The authors concluded that differences in behavior could been seen in children with autism as early as 12 months of age. Specific behaviors such as looking at another’s face, pointing, showing objects, and failing to orient to name proved most significant in predicting whether a child would later be diagnosed with autism. Further research was recommended to determine whether the behavior of children with autism differs from those with cognitive delay. Over all, the results of this study indicated that the presence of autism can be detected much earlier than was customary.
Relevance to the current work
This study provided information regarding early developing deficits in children with autism in social behaviors such as eye gaze and joint attention.


Purpose and description
Paul provided basic information regarding autism spectrum disorders including current diagnostic criteria, the diagnostic process, potential etiologies, and characteristics of the disorders. Specific information was provided regarding social, emotional, and cognitive development and skills, communication, prognosis, and implications for speech-language pathologists assessing and treating children with ASD.

Relevance to the current work
This chapter provided background knowledge regarding ASD.


Purpose
The authors described a “facial automaton for conveying emotions (FACE)” (p. 508). This 3-dimentional android was designed to facilitate emotional and social skill development in persons with autism through interactions aided by a trained therapist.

Method
One typically developing child and one child with autism participated in the initial trial. The robot was situated on a table in front of the child. The therapist sat to the side and facilitated interactions between the children and the robot when necessary.

Results and Conclusion
The typically developing child had an initial positive reaction to the robot, but became uncomfortable with it after the face moved. The child with autism did not initially demonstrate interest, but, with prompting, to attended to the face and provided a verbal reaction to the robot and the robot’s perceived emotion. The authors concluded that the child with autism was not upset by the robot and that it could potentially be used in therapeutic situations.

Relevance to the current work
This paper provided support for using facial expressions made by a humanoid robot in intervention with children with autism.


Purpose
This paper presented rationale, design specifics, and research findings related to the FACE project. The goal of the project was to use the android to facilitate improved social and emotional functioning in persons with autism.

Method
Four participants diagnosed with autism interacted with a humanoid robot in 20 minute sessions. Participants were evaluated using the CARS (Childhood Autism Rating Scales) in two contexts: in the presence of the robot and in the absence of the robot. Participant physiological data were gathered using an unobtrusive measurement system.

Results and conclusion
Although preliminary, results indicated sustained or decreased ratings related to autistic symptoms for all of the subjects with one exception. The participants spontaneously imitated the facial expressions and head movements of the android and followed the android’s eye movements given verbal prompting from the therapist. The authors concluded that this technology could help persons with autism utilize social communication skills.

Relevance to the current work
This paper provided evidence that the ability to imitate and interact socially could be positively influenced by therapeutic interactions with a humanoid robot.


Purpose
This article presented a tutorial for intervention specialists which included a review of literature concerning socioemotional difficulties encountered by children with communication disorders and recommendations for assessment and intervention.

Conclusions
The authors reported that many children with communication disorders also experienced social and emotional difficulties. The authors provided areas in which speech-language professionals needed to become more educated with regard to social and emotional functioning. A brief description of socioemotional development was provided. The impact of communication disorders on socioemotional development and expression was discussed. The authors discussed the role of family in emotional development as well as the influence of communication disorders on typical socioemotional functioning within a family. Suggestions were given for assessment of socioemotional functioning as well as supporting socioemotional development in intervention.

Relevance to the current work
This article provided background on self-regulation and emotional development of children with communication disorders.


**Purpose**

This article described the SCERTS model which detailed important areas of focus in intervention with persons with autism.

**Conclusions**

The name of the models, “SCERTS” was developed based on the main emphases of the model: social communication, emotion regulation, and transactional support. The authors provided rationale for the development of the model and outlined areas of significance within each larger category. Social communication embraced the dual focus of developing joint attention as well as facilitating the increased use of symbols in communication. Emotion regulation encompassed the ability to regulate one’s own emotional state (self-regulation), the ability to enlist the help of others to regulate emotion (mutual-regulation), as well as the ability to regain a regulated state after instances of disregulation. External supports in the educational setting, understanding supports necessary for interaction, assisting family members, and establishing support for professionals were four areas were highlighted in the area of transactional supports. The authors discussed the implementation of this model in realistic settings.

**Relevance to the current work**

The SCERTS model was used as a basis for the therapy conducted in the current study. This article also provided information regarding self-regulation.


**Purpose**

This article provided a brief overview of characteristics of ASD.

**Conclusion**

The etiology of autism was unknown, but related to genetics. Diagnostic criteria included deficits in social functioning and communication as well as repetitive/restricted interests and behaviors. Other associated characteristics which frequently, but not universally, occurred in people with autism included lower IQ, mood and emotional abnormalities, attention deficits/disorders, abnormal sensorimotor functioning, and seizures. Information regarding differential diagnosis and assessment of children with autism was provided, as well as information regarding prognosis and treatment.
Relevance to the current work

This article provided background information regarding characteristics of ASD.


Purpose

The purpose of this article was to provide basic information regarding the characteristics, cause, course, and management of ASD.

Conclusions

The core features of autism included social deficits, communication difficulty, and restricted interests/repetitive and/or stereotyped behaviors. Autism was highly heritable, showing a strong genetic link. A few medical causes were cited in a low percentage of the ASD population; however, a specific cause in the rest of the population with ASD was not clear. Assessment and diagnosis were multidisciplinary. Treatment of ASD included educational, community, and occasional pharmacological supports. Symptoms of ASD tended to last into adulthood, although severity of symptoms varied greatly.

Relevance to the current work

This article provided background information regarding ASD.


Purpose

This thesis reported the rationale for and design of a humanoid robot which could be used in therapy to treat children with autism spectrum disorders.

Rationale

Previous research indicated that children with autism were interested in interacting with robots and displayed more socially engaged behaviors in the presence of a robot. The current robot was designed to extend previous research and design a robot which could be used in interactions with children with autism and therapists to promote generalization of social interaction behaviors.

Design

The robot, named Troy, was designed as an upper-body humanoid robot roughly the size of a 4-year-old child. Troy was designed with two arms with four degrees of freedom each, a neck with two degrees of freedom, and a head made from an LCD monitor housed in a plastic case. Troy was connected to a laptop containing the user interface which allowed for the programming of Troy’s actions and facial expressions. The face of Troy (the LCD screen) was programmed to express basic emotions in a simple, predictable manner. Troy was programmed
with basic actions and expressions to enable him to be used in interactions with children with autism.

Relevance to the current work
The robot reported on in this thesis was used in the current study.


Purpose
This paper presented findings from a longitudinal study designed to measure the effect of a robot on the interactional skills of children with autism over time.

Method
Four children with autism participated in this study. The small humanoid robot was placed on a table connected to a laptop through which it was controlled. An experimenter was present in the room to control the robot. Exposure to the robot began with the robot performing simple, predictable movements and complexity of robot movements was gradually increased over time. A set of specific behaviors (i.e. eye contact, touch, imitation, and physical proximity) was tracked over the course of the study. Qualitative data and observations were also recorded.

Results and Conclusion
Results were variable between the children, but promising. Children showed increased social interactive behaviors over the course of the study and occasionally included another person in their interactions. Generalization of the behaviors to contexts not involving the robot was not tested.

Relevance to the current work
This article provided evidence for the use of a humanoid robot in treatment with children with autism. Data collection methods in this study were similar to those employed in the current work. The need for analysis of generalization was highlighted.


Introduction
This study was in association with the Aurora project. The Aurora project was designed to investigate how the use of interactive robots could aid in the development of basic social skills in persons with autism. The purpose of this particular publication was to provide a qualitative description of the instances of joint attention between children with autism and an experimenter with a robot as the focus of the joint attention.

Method
The current data involved four children with autism with whom the lead author was working. The children ranged in age from 5-10 years and were attending the same elementary school. Video footage for three of these children, ages 5, 6, and 10, was analyzed. All three children were minimally verbal and displayed significant difficulties with social interaction.

The experimenters placed a small humanoid robot (doll) and connected laptop on one wall of a room familiar to the children. Two stationary cameras were positioned in the room, one behind the robot facing outward, the other facing the robot.

Each child participated in as many trials as possible over a 12 week period. Most children came in for nine trials, each about three minutes in length. Each trial was minimally structured. The child was permitted to move about the room freely while the experimenter sat next to the laptop which controlled the robot. During the trials, the experimenter did not initiate interaction, but responded to interaction initiated by the child. The trials lasted until the child indicated a desire to leave the room or until the child became bored after being in the room for three minutes.

Results

One child initiated joint attention with the experimenter by first paying marked attention to the left leg of the doll, which was stuck in an extended position. This drew the attention of the experimenter. The child then vocalized while turning to the experimenter, made eye contact with the experimenter, looked down toward his own leg at the same time as extending and kicking his leg. The authors of the study compared this child’s use of eye gaze to direct another’s attention with a videotaped interaction of typically developing children who also used eye gaze to direct another’s attention.

Two other children responded to bids for joint attention given by the experimenter. One child oriented his body in the direction the experimenter was looking and pointing; however, he did this at the same time the robot’s arm lowered, making it unclear to what the child was responding. The third child responded to the pointing and eye gaze of the experimenter by orienting his body toward the robot, at which the experimenter was looking and pointing. The child furthered the instance of joint attention by taking the experimenter’s hand and pulling it toward the robot. Although a later instance of responding to joint attention by this same child may have actually been a response to movement in the robot, before the end of this interaction, the child established eye contact with the experimenter.

Discussion and Outlook

Children with autism in this study used the same types of strategies for gaining and maintaining the attention of an interactional partner as other communicators. They designed their movements and vocalizations in such a way as to obtain the attention of another, “recipient design skills,” as the authors termed it.

The authors posited that a robot could be a useful object to promote joint attention between children with autism and adults. They hypothesized that the robot could be significant because of its capability for autonomous movement. Regardless of the particular reason, the authors suggested that a robot could be an effective tool to mediate social interaction between children with autism and those with whom they interact.

Relevance to Current Work
This study provided evidence suggesting that using a robot may be an effective way to elicit joint attention. Additionally, this study provided a model, at least in part, for data collection and analysis using video recording and coding.


**Purpose**

This study examined the efficacy of using a naturalistic assessment of joint attention compared with the administration of the ESCS (Early Social Communication Scales). The naturalistic assessment was designed to measure the same behaviors as the ESCS, but in a less-restrictive play context.

**Method**

Twenty children with autism were assessed first with the ESCS and then with a newly-developed, naturalistic play assessment. Levels of initiating and responding to joint attention were measured.

**Results**

Results indicated that the assessments were similar in their measurement of joint attention behaviors.

**Conclusion**

The authors concluded that the naturalistic play assessment was an effective and valid alternative to the more structured assessment.

**Relevance to the current work**

This work provided evidence in support of using naturalistic situations as a context in which to assess joint attention skills in children with autism.


**Purpose**

The purpose of this study was to measure the quality of life of adults with ASD living in Spain.

**Method**

Seventy-four families of individuals with autism answered both questions regarding both objective and subjective quality of life measures.

**Results**

Results indicated that adults with autism had low quality of life due to lack of social circle variety and lack of community supports.
Conclusion
The authors concluded that adults with ASD and their families need increased supports in their community to improve quality of life. They also cited the need for more research in this area.

Relevance to the current work
This article provided information regarding social difficulties in individuals with ASD.


Purpose
The author of this paper described various applications of robots in assessing, diagnosing, and treating autism as suggested by the research conducted at Yale, University.

Conclusions
The author posited that robots could be used in therapy with children with autism as a bridge to greater social competence because these children were highly interested in and motivated by robots. In a study reported by the author, although both typically developing children and children with autism displayed interest in robots, the children with autism displayed interest for longer periods of time in some cases.

The author also cited other uses of robots in relation to children with autism. He suggested that robots could be used to track socially relevant information such as eye gaze, proximity, and vocal prosody to aid in assessment and diagnosis of children with autism. Additionally, robots could be used to gather data on typical behavior patterns in children with autism. The author briefly reported on a study which indicated the visual scanning patterns of people with autism not only differed from typically developing individuals, but also differed from other people with autism.

Relevance to the current work
This paper provided evidence that children with autism were interested in robots and that this type of technology had promise in intervention with children with autism.


Purpose
The purpose of this paper was to describe the behaviors assessed in the Early Social-Communication Scales and provide background, rationale, and research related thereto. Purpose of the ESCS is to provide a structured, functional assessment of social communication skill development.

Organization
The ESCS were organized according to a cognitive developmental framework. Three areas of communicative function were addressed: social interaction, joint attention, and behavior regulation. Social interaction referred to behaviors which drew and kept the attention of an interaction partner. Joint attention referred to behaviors which drew the attention of an interaction partner to an object/event of interest. Behavior regulation behaviors were those which served to meet the needs of one interaction partner via the other interaction partner. Each area of communicative function was further classified into child as initiator and child as responder. Social interaction and joint attention also included an area to quantify behaviors which maintained interactions.

Content

Five stages of cognitive development, based loosely on Piaget’s sensorimotor stages and other relevant research, were described. Behaviors progressed along a continuum from reflexive to intentional. Level 0, the “reflexive or responsive” (p. 249) level, was characterized by behaviors lacking intent and lasted from approximately 0 to 2 months of age. Level 1, dominant from ages 2 to 7 months, was labeled “simple, voluntary actions” (pp. 249-250), as this was when rudimentary intentional behaviors began to emerge. At level 2, the “complex, differentiated interactions” (p. 250) level, children began to tell the difference between interaction partners and to recognize others as a means for social engagement. This stage was dominant from 8 to 12 months. Level 3, the “immediate modification of interactions to feedback” (pp. 250-251) level, was dominant from 13 to 21 months and was characterized by the child’s understanding that changing their actions could produce desired results in their interaction partners. Finally, level 4, the “anticipatory regulation of interaction” level, was the level at which symbolic representations of objects and ideas emerged. This level was dominant after 22 months of age.

Administration, Scoring, and Conclusions

The ESCS could be administered through a parent questionnaire or through direct interaction with the child. Scores were based on the highest level of performance within each of the eight scales. Current evidence in support of the ESCS was discussed as well as limitations and potential objections.

Relevance to the current work

This article provided information regarding the early development and assessment of social communication skills.


Purpose

The authors of this chapter reported how individuals differ in their use of joint attention in different situations. The authors examined these uses in both normally developing children and in children with autism. They provided support for the idea of an underlying construct of joint attention based on the parallels in joint attention development across contexts and across individuals.
Review and Conclusions

The authors reviewed the development of joint attention in the contexts of “shared gaze and verbal reference” (p. 191), “social referencing of adults in ambiguous situations” (p. 192), and as “responses to distress of others” (p. 193). They found that although the motivation behind joint attention behaviors varied with context, all of the infants seemed to use joint attention as a means for gaining social understanding of those around them.

Additionally, the authors examined parallels between the joint attention behaviors in children across contexts including “in the use of gaze with development” (p. 194) and in “individual difference in gaze” (p. 195). They reviewed and article by Sigman and Kasari (1994) which indicated that the amount of referencing eye gaze increased with age in two different contexts. Similarly, they noted that the children in the study who looked at adults more frequently in one situation also looked more frequently at adults in other situations. These observations support the notion that there is an underlying process related to joint attention development and expression.

In reviewing the literature surrounding joint attention in children with autism in different contexts, the authors found that children with autism demonstrated markedly reduced instances of joint attention across contexts, with the exception of seeking to have their needs met. They also noted; however, some research (Kasari et al., 1993b; Sigman et al., 1986) which indicated that children with autism responded as frequently to initiations from their mothers, but that they did not initiate engagement nearly as frequently as typically developing peers. This resulted in difficulty with social interactions, particularly with peers. The authors hypothesize that the deficit in joint attention in children with autism occurs “at the intersection of attention and cognition with affect” (p. 199). In other words, children with autism had difficulty integrating information from facial expressions with other aspects of incoming stimuli. The authors also noted that the deficits in joint attention in children with autism negatively affect their language development.

Relevance to the current work

This chapter provided information regarding joint attention in typically developing children and in children with autism.


Purpose

The purpose of this study was to provide information regarding the prevalence of ASD in the United States.

Method

Information was gathered from 14 sites around the United States regarding the presence of autism in children 8 years of age.
Results
The prevalence of autism was estimated to be 1 in 88 children in the United States.

Conclusion
The prevalence of autism continued to rise from the previous data taken.

Relevance to the current work
This article provided current information regarding the prevalence of ASD.


Purpose
This chapter presented a summary of the social characteristics and social development of children with autism.

Summary and Conclusions
Volkmar provided a brief history of views concerning the disorder as well as a description of the then-current diagnostic criteria for autism contained in the DSM-III. Social development was described in sum and followed by a description of social behaviors of children with autism.

All of the descriptions of the social behaviors of children with autism were supported by the most current research of the time. The early markers of the social behaviors of children with autism included a paucity of eye contact and positive affect for social purposes, lack of alteration of behavior toward unfamiliar and familiar people, and lack of normal displays of affection. At later ages, social behavior of children with autism was characterized by the formation of social connections (although their manner of connecting was passive and/or atypical), demonstrated difficulty with perspective taking, and engagement in odd behaviors. Differentiation between familiar and unfamiliar persons in was noted at this stage. In adolescence and adulthood, it was reported that persons with autism did not always achieve independence and their social impairments continued. Volkmar summarized research that stated that people with autism could desire to establish connections with others, but continued to interact atypically and were often isolated.

Volkmar detailed research studies regarding specific aspects of social engagement including eye contact, facial recognition, play, imitation, language and communication, and non-engagement behaviors. He concluded with notes on treatment of autism and implications for theory.

Relevance to the current work
This chapter provided information regarding social behavior of persons with autism.

Purpose
The purpose of this chapter was to highlight the importance of play in child development of language and to provide a scale to assess play skills.

Conclusions
This chapter detailed information regarding the importance of play in language development. A scale to assess play skills and language development was described. A protocol for the scale, administration instructions, cultural considerations, and information for interpreting results according to typical development patterns were also included. Case examples for various children were provided.

Relevance to the current work
The playscale presented in this chapter was used to evaluate the children who participated in the current study.


Purpose
This chapter described the relationship between social-emotional functioning and language development. Factors influencing social functioning and communication development, guidelines for assessing social-emotional functioning, and suggestions for intervention were also provided.

Conclusions
The author posited that language is, by nature, social and therefore the development of social-emotional competence is intrinsically tied to communicative competence. The author asserted that educators, family members, and intervention specialists need to take social-emotional functioning into account when working with children, particularly those with disabilities.

Relevance to the current work
This chapter provided information regarding the importance of social-emotional functioning in communication and social interactions, not only in early life, but also as children enter academic settings.


Purpose
The purpose of this study was to examine the early social behaviors, or lack thereof, in infants with autism and to address methodological issues identified in previously conducted studies on the subject.
Method

Ten parents of children with autism and 10 parents of children with developmental delays were interviewed using the Detection of Autism by Infant Sociability Interview (DAISI), a semi-structured interview which contains items specifically inquiring into social engagement behaviors which are common among typically developing children. Parents were interviewed about their children prior to their children receiving a diagnosis of autism and no more than two years after the events of interest on the DAISI interview.

Results

Results of the study indicated that children with autism differed significantly from typically-developing children in early developing social skills. Children with autism demonstrated differences both in primary intersubjectivity and secondary intersubjectivity.

Conclusions

The authors concluded that children with autism display social deficits early in life. Evidence from this study supported the idea that social deficits are a key factor in autism and could be used to distinguish children with autism from typically developing children.

Relevance to the current work

This study provided background regarding the social deficits of children with autism.