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A Robotic Therapy Case Study: Developing Joint Attention Skills With a Student on the Autism Spectrum

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Abstract

The purpose of this article is to describe a possible methodology for developing joint attention skills in students with autism spectrum disorder. Co-robot therapy with the humanoid robot NAO was used to foster a student's joint attention skill development; 20-min sessions conducted once weekly during the school year were video recorded and analyzed for joint attention. Robot therapy may be a viable method to improve communication skills in individuals identified with autism spectrum disorder. This particular student was clearly motivated by working with a humanoid robot.

Keywords

autism, joint attention skills, communication, robot

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Autism Spectrum Disorder

A problem of increasing global concern is the dramatic increase of children with autism spectrum disorder (ASD). Statistics in the United States for 2010 identify 1 in 68 American children as on the autism spectrum, a 10-fold increase over 40 years (U.S. Center for Disease Control & Prevention, 2016).

The Diagnostic Criteria for ASD, according to the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*, "include persistent deficits in social communication and social interaction, as manifested by deficits in social-emotional reciprocity, ranging, for example, from abnormal social approach and failure of normal back-and-forth conversations... to failure to initiate or respond to social interactions" (Messent, 2013). Level 3 autism is defined according to the *Diagnostic and Statistical Manual of Mental Disorders* as an individual on the autism spectrum scale who requires very substantial support and who experiences severe deficits in verbal and nonverbal social communication skills which cause severe impairments in functioning, very limited initiation of social interaction, and minimal response to social advances of others. Children with ASD exhibit communication deficits, social skill challenges, and repetitive patterns of behavior, with symptoms present usually before the child is 3 years old (Hallahan, Kauffman, & Pullen, 2015; Warreyn & Roeyers, 2014).

Joint Attention Skills

Typically developing children learn to identify, use, and follow nonverbal cues even before they learn to talk and communicate verbally (Owens, 2016). Joint attention is the ability to share a common focus on something (people, objects, a concept, an event, etc.) with someone else. It involves the ability to gain, maintain, and shift attention (Woods & Wetherby, 2008). Skills such as pointing, looking where another individual is directing, as well as maintaining eye contact are all forms of nonverbal communication that are commonly learned and used before using speech to interact with others (Poon, Watson, Baranek, & Poe, 2012). Children with ASD often have difficulty learning these "joint attention" skills (Dalton, 2011; Dawson et al., 2004; Leekam & Ramsden, 2006; Wong & Kasari, 2012), because these skills involve not only being attentive to the gestures (physical and verbal) demonstrated by the other person but also exhibiting an appropriate response. Since this ability is a prerequisite to learning language and having virtually any effective communication with others, it is important that all students learn these skills (Hallahan et al., 2015). Thus, we decided to use a humanoid robot to facilitate this joint attention development.

The NAO Robot

A review of the literature suggests using a robot is a viable option for improving joint attention (Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014; Billard, Robins, Nadel, & Dautenhahn, 2007; Kahn et al., 2012; Kim et al., 2013; Paparella & Freeman, 2015; Severson, 2010; Staudte & Crocker, 2011). An example of a robot that interacts well with children is the NAO humanoid robot shown in Figure 1 (www.aldebaran.com/en/cool-robots/nao). NAO is roughly 2′ tall with facilities for speech recognition, object recognition, mobility, and gesturing (doc.aldebaran.com/2-1/family/nao_h25/index_h25.html). A useful feature of the NAO robot is its programmability. It comes off the shelf with several behaviors that can be used in human–robot interaction, and other behaviors can be implemented for special-purpose behaviors. At the time of this writing, the price of NAO is $10,000 USD. Educational establishments and teachers can request a quote at https://www.aldebaran.com/en/cool-robots/buying-a-robot; NAO has four directional microphones and loudspeakers and is equipped with two cameras that film his environment.

Robots which interact socially with children on the autism spectrum may prove to be useful tools for communication therapies. Diehl, Schmitt, Villano, and Crowell (2012) compared students' interactions with a robotic dinosaur, a human, and touchscreen computer. Diehl et al. (2014) examined the physical appearance of robots, the content and goals of human–robot interactions, types of evaluation studies, and data collection and analysis. Recent systematic reviews of the literature argue that co-robot therapy has potential to elicit different types of behaviors in children on the autism spectrum of different ages and levels of ability.

Figure 1. The NAO robot.

Methodology

For 7 months, we videoed a student receiving 20-min speech-therapy sessions with the NAO robot once a week. All procedures were vetted through the Southern New Hampshire University Institutional Review Board with permissions signed by school district personnel and the student's parents. The student was an 8-year-old boy in third grade. He was identified with Level 3 autism which is defined according to the *Diagnostic and Statistical Manual of Mental Disorders* as an individual on the autism spectrum scale who requires very substantial support and who experiences severe deficits in verbal and nonverbal social communication skills which cause severe impairments in functioning, very limited initiation of social interaction, and minimal response to social advances of others (Messent, 2013). His speech language pathologist (SLP) gave the following description of the student at the beginning of the sessions:

> He shows deficits in maintaining attention, joint attention, and taking initiative. He participates in special and general education classes, receives direct special education instruction and gets support from paraprofessionals. He participates in individual and group speech therapy sessions. He plays games, watches TV shows, and scripts them both physically and mentally, showing a strong cognitive inner life. He reads with comprehension at the kindergarten level.

The therapy sessions were conducted in the school's playroom. It was a large room with play objects scattered about, for example, a swing, trampoline, blocks, toys, a yoga ball, and so forth. See Figure 2 for the configuration of the robot operator, the robot, the SLP, and the student.

Video recording took place during the class period in which the student with ASD used the NAO robot. The video camera was set up on a tripod and was turned on just prior to the student coming to the room. The only people in the room were the SLP, student, and robot operator thus eliminating unnecessary distractions.

We analyzed the video charting for both response to joint attention and initiating joint attention. The beginning of the school year comprised activities to encourage "*response* to joint attention" development. For example, the robot gave the student a directive, and the researchers charted the student's responses (response to joint attention) to the directive. The robot might say, "Touch your head." The student would be charted on whether or not he touched his head. Charting looked at if the student responded to the robot's directive, if the student responded to the robot's directive with a prompt from the SLP, or if the student did not respond to the robot's directive.

The remainder of the year comprised activities to encourage "*initiating* joint attention" development. For initiating joint attention, the student gave the robot a directive. For example, the student might say, "Look at the window."

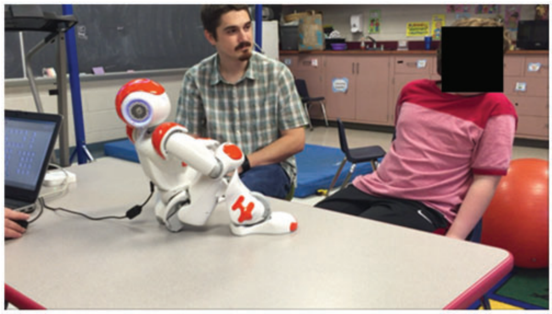

Figure 2. Setting configuration.

	Total Directives	No Response	Correct without Prompting	Correct with Prompting
Nov 2 2015	105	4	64	37
Nov 5 2015	96	7	60	29
Nov 9 2015	138	11	95	32

Figure 3. Procedure for recording video data.

The robot would then turn and look at the window. Charting looked at if the student initiated a directive to the robot and SLP with or without a prompt from the SLP, or if the student did not provide a directive (Figure 3).

We used Soft System Methodology (SSM) to analyze the robot therapy sessions retrospectively. SSM is designed for difficult problems in human affairs in which a vague, notional system is discovered and then improved upon iteratively in a cycle of inquiry and discovery (Checkland, 2000). Figure 4 shows the methodology and its underlying principles.

During the first 10 cycles of the methodology, that is, 10 sessions over a 5-week period, accommodations were made involving the syntax and intonation of the robot's directives or reinforcements and game content and the movement of the robot's head in the direction of interest. A new game "Old MacDonald Had a Farm" was introduced in which the student answered directives of the form "What does the X say?"

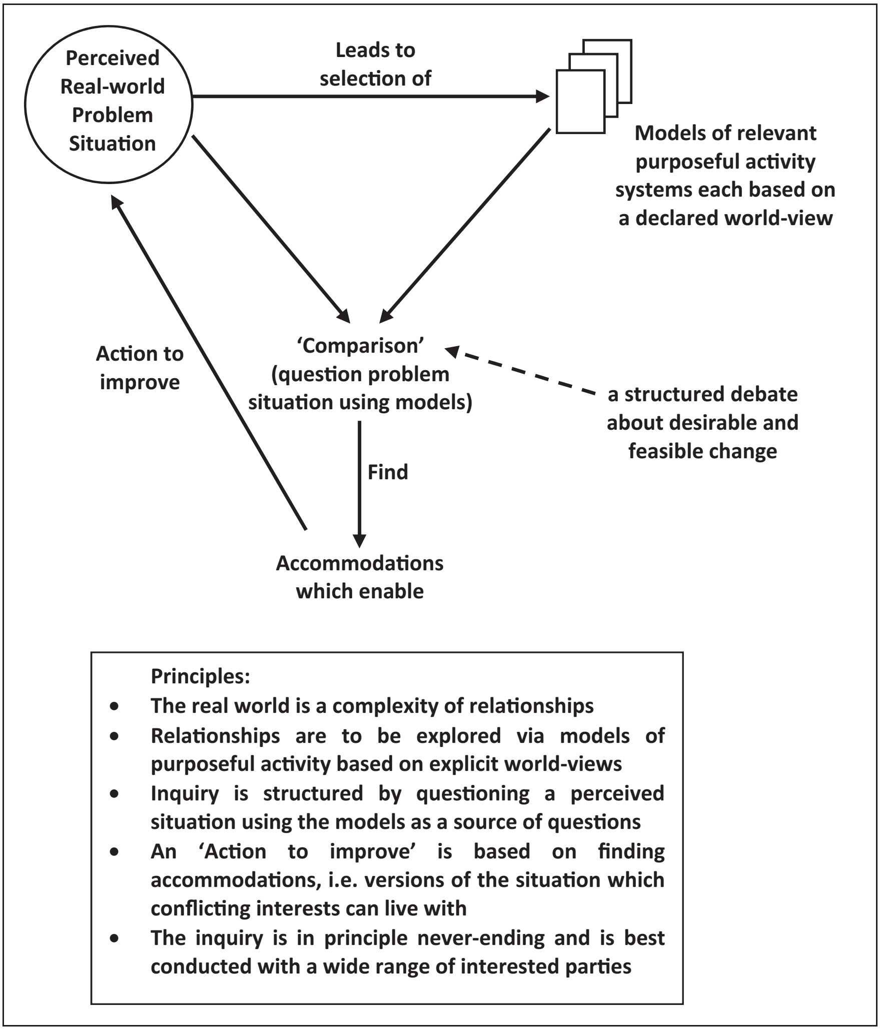

Figure 4. Cycle of inquiry and discovery (Checkland, 2000).

We completed 20 cycles of SSM. As an example, at the start of Cycle 9, the problem situation had remained "improve skills in joint attention" but the student had made considerable progress according to the SLP and special education teacher. This led to considerations of related activities including the home (he likes to talk about the robot), routine school tasks (he gets bored with teachers but does not get bored with the robot), group therapy (no noticeable improvement because other group members have various disabilities), and programming the robot (some behaviors are simple to implement but others are

Focus	Session	Date	Total # of directives issued to the student	Total # of student's responses without needing prompting	Total # of student's responses but only with prompting	Total # of directives to which the student did not respond	% without prompting	% with prompting	% no response
Responding to Joint attention among robot, student, and SLP	1	Nov 2 2015	105	64	37	4	61	35	4
	2	Nov 5 2015	96	60	29	7	63	30	7
	3	Nov 9 2015	138	95	32	11	69	23	8
	4	Nov 12 2015	95	80	10	5	84	11	5
	5	Nov 16 2015	118	93	20	5	79	17	4
	6	Nov 19 2015	126	84	30	12	67	24	9
	7	Nov 23 2015	152	119	26	7	78	17	5
	8	Nov 30 2015	148	114	31	3	77	21	2
Initiating Joint Attention among robot, student, and SLP	9	Dec 3 2015	104	78	25	1	75	24	1
	10	Jan 4 2016	118	72	42	4	61	36	3
	11	Jan 7 2016	72	56	14	3	78	18	4
	12	Jan 11 2016	30	21	8	1	70	27	3
	13	Jan 14 2016	73	56	15	2	76	21	3
	14	Jan 25 2016	86	55	29	2	64	34	2
	15	Jan 28 2016	88	70	17	1	80	19	1
	16	Feb 11 2016	52	36	13	3	69	25	6
	17	Mar 24 2016	98	76	20	2	78	20	2
	18	Mar 31 2016	89	71	15	3	80	17	3
	19	Apr 14 2016	70	57	10	3	82	14	4
	20	May 5 2016	53	40	11	2	75	21	4

Figure 5. Data chart.

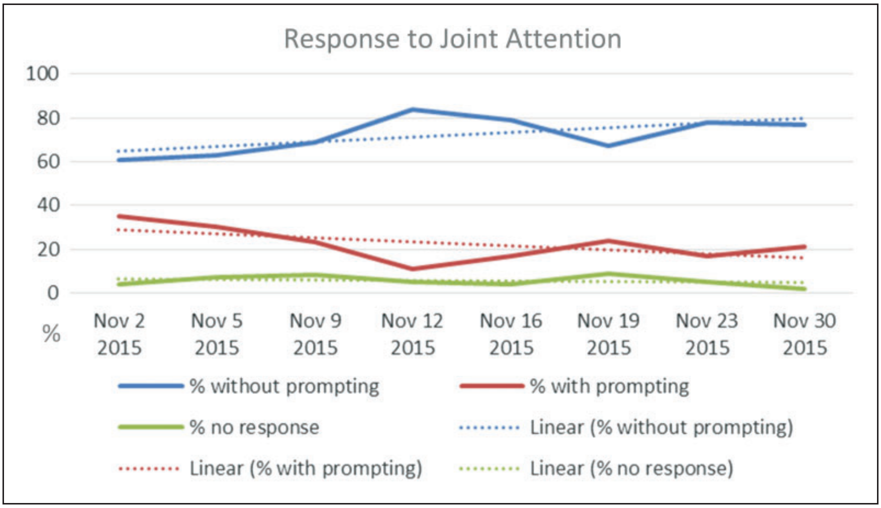

Figure 6. Response to joint attention.

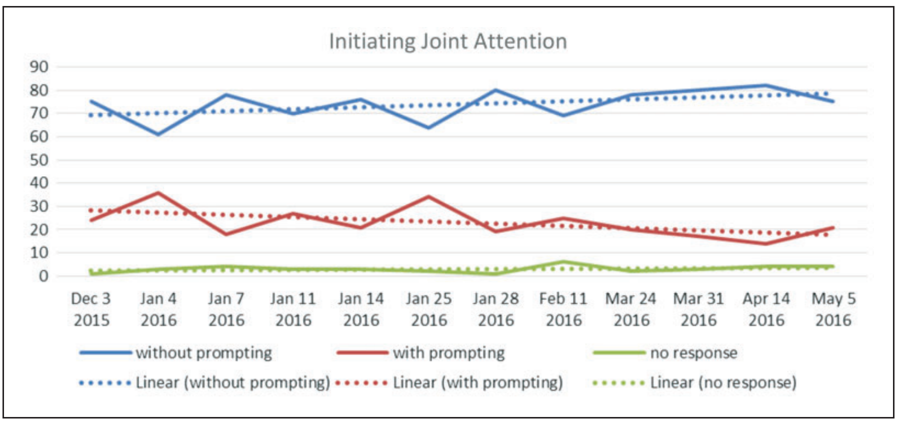

Figure 7. Initiating joint attention.

difficult and time-consuming). After debating these activities with the SLP, it was agreed to find accommodations to introduce *initiating* joint attention skills.

Thus, in Cycle 10, the problem situation was restated "to improve the student's" *initiating* joint attention skills. The games were improved as follows: During the "Everybody look at X" game, the robot asks the SLP and the student to take a turn. If the student responds, the robot turns its head in the direction of X. During the "What does the X say?" game, the robot likewise asks the SLP and the student to take a turn. If the student responds, the robot produces the sound of X. The SLP prompts the student with cue cards "Everybody look at ___" or "What did the ___ say?" During Cycle, 10 the robot asked the student to take a turn 16 times. Video analysis showed that he responded correctly 11 times and responded correctly but only with SLP encouragement 5 times. Based on this result, it was agreed to continue these games several more cycles during which the SLP will try to fade out the cue cards (Figure 5).

All students have good days and bad days for a variety of reasons: incidents at home before coming to school, incidents occurring on the bus on the way to school, incidents with teachers or peers in the school environment, and often for students on the autism spectrum, sensory overload issues. All may affect daily academic and behavioral achievements. Unfortunately, this student's communication skills have not yet achieved a level for him to communicate these types of specifics to others. To better see the "big picture" while including data outliers specified by the student's "bad days—lack of responsiveness," linear charting of the data was done (Figures 6 and 7).

The solid lines represent the actual percentages from Figure 5. The dotted lines are linear trend lines based on the actual percentages. The graphs indicate the student made progress in both *response* to joint attention development and *initiating* joint attention development with and without prompts, that is, the trend lines for "with prompting" decrease over time while the trend lines for "without prompting" increase over time. These results are more significant when one considers that there is some degree of drag on progress because the content of the games became more challenging over time, and also some new games were introduced periodically. The SLP noted that the student had made significant improvements:

> He needs less prompting/encouragement to engage in an activity appropriately. He is initiating on a much more frequent basis (for him) and is not as difficult to redirect back to a task when he is distracted by internal thoughts. He appears to attend to his peers more as well.

Conclusions

It is not definitively known the extent to which robot therapy contributed to the student's improvement. Other factors might include his music therapy, school activities, and natural biological maturation. However, we feel the NAO robot was clearly a motivational factor for this student who had very limited communication skills. His mother, the speech pathologist, and the special educator all reported that “he likes to talk about the robot” and that “he gets bored with teachers but doesn’t get bored with the robot”. The speech pathologist reported increased verbal production when the student’s therapy was “robot based” as opposed to working with the speech therapist alone. This suggests engagement with the robot may enhance students’ interest in an activity and thus may motivate students to improve their joint attention skills. It is important to identify specifically which technologies and methodologies can be used to facilitate engagement and communication skill development in students with disabilities, as acquiring joint attention skills subsequently improving communication skills is an important lifelong skill significantly impacting students’ quality of life.

Implications

Improvements were noted in the student’s “response to joint attention skills,” “initiating joint attention skills,” and communicating while needing “increasingly fewer prompts” from the SLP. This suggests robot therapy may be a viable option to use to facilitate communication skill development in students identified on the Autism Spectrum. These preliminary observations should form a basis for formal research studies to be conducted in the future.

Declaration of Conflicting Interests

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