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Effects of a Socially Interactive Robot on the Conversational Turns Between Parents and Their Young Children with Autism

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KEY WORDS

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Autism spectrum disorder

ABSTRACT

The effects of a socially interactive robot on the conversational turns between four young children with autism and their mothers were investigated as part of the intervention study described in this research report. The interventions with each child were conducted over 4 or 5 days in the children's homes where a practitioner facilitated child-robot and child-mother interactions using robot produced speech and movements. Results showed that the conversational turns between the children and their mothers increased from a nonintervention, baseline condition to the intervention phases of the study for all the children as a group and for all four children individually. The manner in which socially interactive robots might be incorporated into interventions with young children with autism and other disabilities is described.

Young children with developmental disabilities, and particularly children with autism spectrum disorders, often demonstrate problems with reciprocity, joint attention, turn taking, and other social interaction skills (e.g., Charman et al., 2003; Dawson et al., 2004; Trevarthan & Daniel, 2005). Difficulties or deficits in the social abilities of these children are often sources of delays or problems in communication and language development that warrant interventions to improve their social interactional functioning (e.g., Bono, Daley, & Sigman, 2004; Christensen-Sandfort & Whinnery, 2011; Ingersoll, 2011).

The purpose of the study described in this research report was to evaluate the effects of a socially interactive robot on the conversational turns between young children with autism and their mothers as part of interventions in the children's homes to promote their acquisition of communication, language, and other socially interactive skills (Dunst, Prior, & Trivette, 2012). Popchilla, a chinchilla-looking social robot, was used to engage the children in child-robot and child-mother interactions using programmable speech and robot arm, ear, mouth, and eye movements controlled by a practitioner to engage the children in social interactions (Interbots, 2011). The study was conducted as part of a line of research on the utility of socially interactive robots for improving the social-communicative competence of young children with autism and other developmental disabilities (Dunst, Prior, Hamby, & Trivette, 2013; Dunst, Trivette, Prior, Hamby, & Embler, 2013a, 2013b).

The conversational turns between the children and their mothers were assessed in terms of the number of vocal sounds including coos, squeals, babbles, or words initiated by a child with a subsequent response by a mother within five seconds or initiated by a mother and responded to by her child also within five seconds (LENA Foundation, 2013). Conversational turns were digitally recorded using the Language ENvironment Analysis (LENA) system for later analysis (Richards, Gilkerson, Paul, & Xu, 2008). LENA has been increasingly used to record and analyze the vocal production and conversational turns of young children with autism (e.g., Cook, McCauley, & Esposito, 2013; Warren, Gilkerson, & Richards, 2008; Warren et al., 2010). Findings from studies of children with and without autism indi-

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cate that LENA can reliably identify differences in the language learning environments and emergent language abilities of children with autism and typically developing children (Cook et al., 2013; Gilkerson & Richards, 2009; Oller et al., 2010; Yoder, Oller, Richards, Gray, & Gilkerson, 2013). To the best of our knowledge, our study of a socially interactive robot is the first to use LENA to document the effects of social robots on conversational turns of young children with disabilities.

METHOD

Participants

The participants were four children (3 males, 1 female) with diagnoses of autism and their mothers. Table 1 includes background information about the children. The children ranged in age from 36 to 59 months at the start of the study. Both the *Developmental Observation Checklist Scale* (Hresko, Miguel, Sherbenou, & Burton, 1994) and the *Childhood Autism Rating Scale* (Schopler, Van Bourgondien, Wellman, & Love, 2010) were completed on the children. The children's developmental ages ranged between 15 and 43 months and their developmental quotients (DQs) ranged between 28 and 73. The DQs indicate that the children had mild-moderate to profound developmental delays. Two of the children had symptoms of severe autism spectrum disorders and two children had symptoms of mild-to-moderate autism spectrum disorders (Schopler et al., 2010).

The children's mothers were between 30 and 39 years of age. Two of the mothers had completed high school or some schooling beyond high school, and two mothers had master's degrees. Two of the mothers worked full time outside the home, one mother worked part-time outside the home, and one mother did not work outside the home. All the mothers were married.

Procedure

A multiple baseline design across children (Barlow, Nock, & Hersen, 2009) was used to conduct the study and collect the conversational turns data. The research design included a baseline, nonintervention condition and four or five intervention sessions for each child, each occurring on separate days. The baseline and intervention sessions each lasted between 15 and 25 minutes. Data from the first 15 minutes of both the baseline and each intervention session were the focus of analysis reported in this paper.

The baseline condition involved conversational turn recordings where Popchilla was available to each child but where the social robot produced no speech or movements. Each of the intervention sessions involved investigator-facilitated robot interactions using professionally recorded speech by a child actor together with robot arm, ear, mouth, and eye movements. The particular sounds, words, phrases, songs, rhymes, and other speech used during the intervention sessions are listed in Appendix A. The sounds and speech that were used in the study were selected in order to have behavior-engaging features and include phrases that would elicit or evoke joint attention, turn taking, and other socially interactive behavior (see Dunst, Prior et al., 2013).

Conversational Turns

Conversational turns were defined as a "vocal sound such as a coo, squeal, babble, or word(s) initiated by a child with a subsequent response by a [mother] within five seconds, or vice versa. Overlapping speech segments, coughs, cries, and other vegetative and fixed signals [did] not contribute to the conversational turn count" (LENA Foundation, 2013). The conversational turn count used as the dependent measure in the analyses described in this research report is a "measure of adult-child interactions, or more specifically of alternations between key child segments and adult [speech] segments" (Warren et al., 2010, p. 560).

Continuous recordings of conversational turns were made using LENA digital language processing devices during the baseline and intervention phases of the studies (Xu, Yapanel, & Gray, 2009). The recorders fit into a small pocket of a vest worn by a child. The recorder

Table 1
Characteristics of the Children with Autism in the Conversational Turns Study

		Developmental Observation Checklist Scale			Childhood Autism Rating Scale		
Child[a]	Gender	Chronological Age	Developmental Age	Developmental Quotient	Raw Score	Percentile	Severity
Adam	Male	36	22	61	37	42	Severe
Brad	Male	42	27	64	36	38	Mild/moderate
Chloe	Female	54	15	28	41	65	Severe
Daren	Male	59	43	73	31	16	Mild/moderate

[a]All of the children's names are fictitious to protect their identities.

digitizes all sounds and language produced in the immediate environment and transfers the audio data to a laptop computer for subsequent analysis using the LENA language environment software package.

The LENA software includes speech-identification capabilities that permit separation of all language and sounds recorded during a session into adult male and adult female speech, target child speech, the speech of other children if present, noise, television or radio sounds, etc. from which conversational turns are abstracted. The main types of data that were collected as part of the study included child vocalizations and adult (parent) words as well as conversational turns which were the focus of analyses in this research report (LENA Foundation, 2013).

Data Analysis

The conversational turn data were analyzed in a number of ways to assess whether child-robot interactions had the effect of increasing the number of conversational turns between the children and their mothers. We first computed for each child the total number of conversational turns during the first 15 minutes of baseline recordings and for each of the four or five 15-minute blocks (days) of intervention recordings. These data were used to calculate group means and standard deviations in order to compute Cohen's *d* effect sizes for baseline vs. intervention phase differences for all children combined. Second, we computed Cohen's *d* effect sizes for each child for baseline vs. intervention phase differences to ascertain if the effects of child-robot interactions on conversational turns were similar or different. Cohen's *d* effect sizes were computed as the differences in the mean scores for the baseline vs. intervention phases divided by the pooled standard deviation for the two conditions for the children as a group and for each individual child (Dunst & Hamby, 2012).

RESULTS

The average number of conversational turns during the baseline phase of the study was 9.50 (SD = 10.79) and the average number of conversational turns during all of the intervention sessions combined was 24.89 (SD = 12.81) for the children as a group. The Cohen's *d* effect size for the between condition differences was 1.30. This indicates that Popchilla had a very large effect on the conversational turns between the children and their mothers.

The average number of conversational turns during the baseline and each of the five intervention sessions are shown in Figure 1. The average number of conversational turns for the five intervention sessions ranged between 15.75 (SD = 14.32) and 34.33 (SD = 4.51). The Cohen's *d* effect sizes for the mean differences between the baseline condition and each of five intervention sessions were 0.94, 1.31, 1.87, 0.49, and 3.00 respectively. The effect sizes were medium to very large. The results indicate that the increases in conversational turns between the children and their mothers occurred immediately after the interventions were begun and continued to have positive effects for all days of intervention.

Figure 2 shows the effect sizes for the baseline vs. each intervention phase of the study for the four children individually. The child-robot interactions had discernible effects on the conversational turns between all of the children and their mothers. The effects for Brad and Chloe were particularly pronounced during 4 of the 5 intervention sessions as evidenced by very large effect sizes. The effects for Daren were medium-to-large for 2

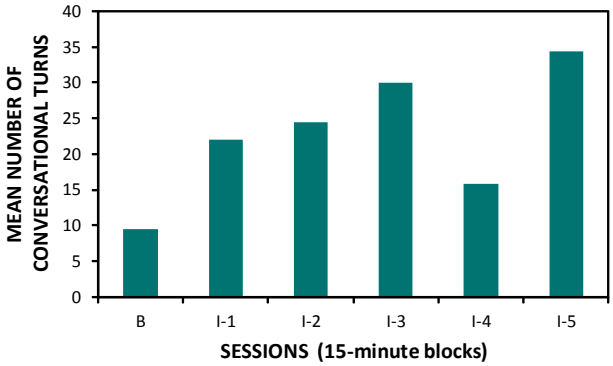

Figure 1. **Average number of conversational turns between the children and their mothers during the baseline (B) and five intervention (I) sessions (days).**

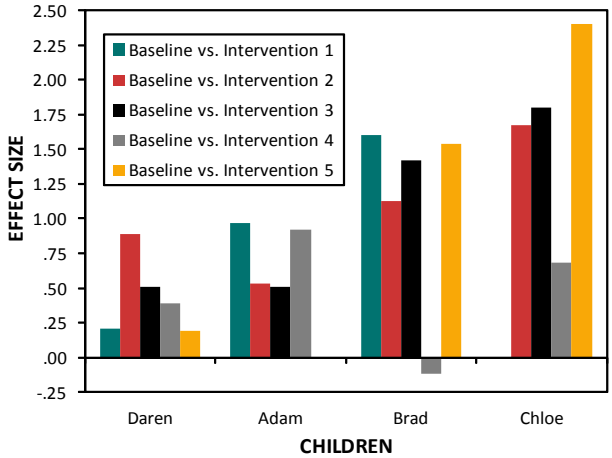

Figure 2. **Cohen's *d* effect sizes for the differences in conversational turns for the baseline vs. each of the five 15-minute blocks (days) of intervention. (NOTE. The children's names are fictitious to protect their identities.)**

of the 5 intervention sessions and medium-to-large for all five intervention sessions with Adam.

DISCUSSION

Findings reported in this paper indicated that Popchilla had positive effects on the conversational turns between the children and their mothers. This was found in both the group and individual child data analyses. The results showed that the socially interactive robot was effective in terms of improving reciprocity between the children and their mothers as part of the interventions used to improve the children's social-communication behavior.

Young children with autism as well as children with other types of developmental disabilities often demonstrate delays or deficits in prelinguistic communication and social interactions (e.g., Carvajal & Iglesias, 2002; Trevarthan & Daniel, 2005). These delays or difficulties often manifest themselves in terms of the children's joint attention, turn-taking, and other social interaction skills (e.g., Naber et al., 2008; Toth, Munson, Meltzoff, & Dawson, 2006). One particular area in which these children have noteworthy problems is the conversational turns with others (Conti-Ramsden & Perez-Pereira, 1999; Mahoney & Robenalt, 1986; Stojanovik, 2006; Warren et al., 2010), warranting interventions to improve their functions.

Studies of the conversational turns between young children with or without autism and their parents using LENA to assess child-adult interactional patterns show that children with autism engage in fewer vocal turn-taking episodes compared to typically developing children (Gilkerson & Richards, 2009; Warren et al., 2008; Warren et al., 2010). Warren et al. (2010) also found that LENA was sensitive in detecting the effects of therapy on the conversational turns of children with autism. We also found that LENA proved to be useful for detecting changes in conversational turns among young children with autism during intervention sessions using a socially interactive robot for improving child and mother vocal turn-taking.

Autism by definition entails impairments in the social interactions and language learning of children diagnosed with this condition (American Psychiatric Association, 2000). Findings from the study described in this research report together with findings from our study on the vocalization production of children with autism indicate that Popchilla can be a useful tool for improving both social interaction skills and language learning (Dunst, Hamby, Trivette, Prior, & Derryberry, 2013). The use of the social robot would therefore seem warranted as one way of improving the social-communication skills of young children with autism.

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders: DSM-IV-TR* (4th Rev. ed.). Arlington, VA: Author.

Barlow, D. H., Nock, M., & Hersen, M. (2009). *Single case experimental designs: Strategies for studying behavior for change* (3rd ed.). Boston, MA: Pearson/Allyn and Bacon.

Bono, M. A., Daley, T., & Sigman, M. (2004). Relations among joint attention, amount of intervention and language gain in autism. *Journal of Autism and Developmental Disorders, 34*, 495-505.

Carvajal, F., & Iglesias, J. (2002). Face-to-face emotion interaction studies in Down syndrome infants. *International Journal of Behavioral Development, 26*, 104-112.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Drew, A., & Cox, A. (2003). Predicting language outcome in infants with autism and pervasive developmental disorder. *International Journal of Language and Communication Disorders, 38*, 265-285.

Christensen-Sandfort, R. J., & Whinnery, S. B. (2011). Impact of milieu teaching on communication skills of young children with autism spectrum disorder. *Topics in Early Childhood Special Education*. Advance online publication. doi:10.1177/0271121411404930.

Conti-Ramsden, G., & Perez-Pereira, M. (1999). Conversational interactions between mothers and their infants who are congenitally blind, have low vision, or are sighted. *Journal of Visual Impairment and Blindness, 93*, 691-703.

Cook, M. R., McCauley, A. W., & Esposito, M. (2013, April). *Analysis of language learning environments of preschoolers with autism and typical peers*. Presentation made at The LENA International Conference 2013, Denver, CO.

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology, 40*, 271-283.

Dunst, C. J., & Hamby, D. W. (2012). Guide for calculating and interpreting effect sizes and confidence intervals in intellectual and developmental disabilities research studies. *Journal of Intellectual and Developmental Disability, 37*, 89-99. doi:10.3109/13668250.2012.673575.

Dunst, C. J., Hamby, D. W., Trivette, C. M., Prior, J., & Derryberry, G. (2013). Vocal production of young children with disabilities during child-robot interactions. *Social Robots Research Reports*, Number 5. Available at http://www.socialrobots.org/reports/SocRobotRpt_5.pdf.

Dunst, C. J., Prior, J., Hamby, D. W., & Trivette, C. M. (2013). Influences of a socially interactive robot on the affective behavior of young children with disabilities. *Social Robots Research Reports*, Number 3. Available at http://www.socialrobots.org/reports/SocRobotRpt_3.pdf.

Dunst, C. J., Prior, J., & Trivette, C. M. (2012, March). *Utility of socially interactive robots for intervening with young children with autism spectrum disorders*. Presentation made at the 5th annual Western North Carolina Conference on Autism and Autism Spectrum Disorders, Asheville, NC. Available at http://utilization.info/presentations.php.

Dunst, C. J., Trivette, C. M., Prior, J., Hamby, D. W., & Embler, D. (2013a). Parents' appraisals of the animacy and likeability of socially interactive robots for intervening with young children with disabilities. *Social Robots Research Reports*, Number 2. Available at http://www.socialrobots.org/reports/SocRobotRpt_2.pdf.

Dunst, C. J., Trivette, C. M., Prior, J., Hamby, D. W., & Embler, D. (2013b). Parents' judgments of the acceptability and importance of socially interactive robots for intervening with young children with disabilities. *Social Robots Research Reports*, Number 1. Available at http://www.socialrobots.org/reports/SocRobotRpt_1.pdf

Gilkerson, J., & Richards, J. A. (2009). *The power of talk: Impact of adult talk, conversational turns, and TV during the critical 0-4 years of child development* (LTR-01-2). Boulder, CO: LENA Research Foundation. Retrieved from http://www.lenafoundation.org.

Hresko, W., Miguel, S., Sherbenou, R., & Burton, S. (1994). *Developmental Observation Checklist System: A systems approach to assessing very young children: Examiner's manual*. Austin, TX: Pro-Ed.

Ingersoll, B. (2011). The differential effect of three naturalistic language interventions on language use in children with autism. *Journal of Positive Behavior Interventions, 13*, 109-118. doi:10.1177/1098300710384507.

Interbots. (2011). *Popchilla interactive robot*. Pittsburgh, PA: Author. Retrieved from http://www.interbots.com.

LENA Foundation. (2013). *LENA core reports*. Retrieved from http://www.lenafoundaation.org/ProSystem/Reports.aspx.

Mahoney, G., & Robenalt, K. (1986). A comparison of conversational patterns between mothers and their Down syndrome and normal infants. *Journal of the Division for Early Childhood, 10*(2), 172-180. doi:10.1177/105381518601000208.

Naber, F. B. A., Bakermans-Kranenburg, M. J., Van Ijzendoorn, M. H., Dietz, C., Van Daalen, E., Swinkels, S. H. N., Buitelaar, J. K., & Van Engeland, H. (2008). Joint attention development in toddlers with autism. *European Child and Adolescent Psychiatry, 17*, 143-152.

Oller, D. K., Niyogi, P., Gray, S., Richards, J. A., Gilkerson, J., Xu, D., Yapanel, U., & Warren, S. F. (2010). Automated vocal analysis of naturalistic recordings from children with autism, language delay, and typical development. *Proceedings of the National Academy of Sciences, 107*(30), 13354-13359. doi:10.1073/pnas.1003882107.

Richards, J. A., Gilkerson, J., Paul, T., & Xu, D. (2008, September). *The LENA automatic vocalization assessment* (LTR-08-1). Boulder, CO: LENA Foundation. Retrieved from http://www.lenafoundation.org/Research/TechnicalReports.aspx.

Schopler, E., Van Bourgondien, M. E., Wellman, G. J., & Love, S. R. (2010). *Childhood autism rating scale, second edition (CARS2)*. Los Angeles, CA: Western Psychological Services.

Stojanovik, V. (2006). Social interaction deficits and conversational inadequacy in Williams syndrome. *Journal of Neurolinguistics, 19*(2), 157-173. doi.org/10.1016/j.jneuroling.2005.11.005.

Toth, K., Munson, J., Meltzoff, A. N., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. *Journal of Autism and Developmental Disorders, 36*, 993-1005.

Trevarthan, C., & Daniel, S. (2005). Disorganized rhythm and synchrony: Early signs of autism and Rett syndrome. *Brain and Development, 27*, S25-S34.

Warren, S. F., Gilkerson, J., & Richards, J. A. (2008). *Automatic measurement of the language learning environment of children with ASD* [Powerpoint presentation]. Boulder, CO: Infoture. Retrieved from www.lenafoundation.org.

Warren, S. F., Gilkerson, J., Richards, J. A., Oller, D. K., Xu, D., Yapanel, U., & Gray, S. (2010). What automated vocal analysis reveals about the vocal production and language learning environment of young children with autism. *Journal of Autism and Developmental Disorders, 40*, 555-569. doi:10.1007/s10803-009-0902-5.

Xu, D., Yapanel, U., & Gray, S. (2009, February). *Reliability of the LENA Language Environment Analysis System in young children's natural home environment* (LTR-05-2). Boulder, CO: LENA Foundation. Retrieved from http://www.lenafoundation.org/Research/TechnicalReports.aspx.

Yoder, P. J., Oller, D. K., Richards, J. A., Gray, S., & Gilkerson, J. (2013). Stability and validity of an au-

tomated measure of vocal development from day-long samples in children with and without autism spectrum disorder. *Autism Research, 6*, 103-107. doi:10.1002/aur.1271.

Appendix A

Professionally Recorded Sounds and Speech Used in the Conversational Turns Study

Sounds and Words[a]	Phrases	Songs and Rhymes[b]
Ears	All done	ABC Song
Eyes	Can you do this?	A Peanut Sat
Foot	Can you do this? (raises left arm)	Do you want me to sing more?
Great!	Can you do this? (raises right arm)	Down By the Bay
Ha, ha, ha (laughing)	Can you do this? (raises both arms)	Hooorrrayyy!!!! (music and dance)
Hi	Can you do it again?	If You're Happy and You Know It
Mmmmm	Can you give it to mommy?	Itsy Bitsy Spider
Mouth	Can you give it to daddy?	Mother Goony Bird
Ouch	Can you move your head?	Old McDonald
Songs	Can you put the hat on?	Twink-A-Link
Tail	Can you shake your arms?	Wheels on the Bus
Tummy	Can you show mommy a happy face?	
Wheee...wheee!	Dance with me	
Yay	Do you want to play?	
Yeh, yeh	Do you want to sing?	
Adam	Give some to mommy/daddy	
Brad	Give the ball to daddy	
Chloe	Give the ball to mommy	
Daren	Give the book to daddy	
	Give the book to mommy	
	Give the doggy to daddy	
	Give the doggy to mommy	
	Give the hat to your daddy	
	Give the hat to your mommy	
	Give the truck to daddy	
	Give the truck to mommy	
	Good bye	
	How are you?	
	I am happy	
	I am hungry, feed me	
	I don't like that	
	(If correct) Yay, you did it	
	(If wrong) Try again	
	I see something green, show me something green	
	Let's play	

Appendix A, continued.

Sounds and Words[a]	Phrases	Songs and Rhymes[b]
	Let's stop for today	
	Look at the block	
	Look at the book	
	Look at the doggy	
	Look at the truck	
	My name is Popchilla	
	Mmmmm, yummy, I like that	
	Now you try, we will follow you	
	Point to _____	
	Point to my nose	
	Popchilla is getting tired	
	Roll me the ball	
	Roll the truck to me	
	See you later	
	Show daddy	
	Show me the book	
	Show me the doggy	
	Show me where the ball is	
	Show mommy	
	Sing with me	
	Touch my _____	
	That was fun!	
	What is your name?	
	Where is my hat?	
	Where is your daddy?	
	Where is your mommy?	
	Where is your nose	
	Who is that?	
	Wow, wow, wow	
	You did it!	
	You did it! You did it!	
	You eat some	
	You try	

[a] The children's names listed below are fictitious to protect their identities.

[b] The lyrics for each of the songs and rhymes were part of the software used to engage the children in child-robot interactions.