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Influences of a Socially Interactive Robot on the Affective Behavior of Young Children with Disabilities

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KEY WORDS

Socially interactive robot
Popchilla
Child-robot interactions
Intervention
Child affect
Child interests
Child emotions
Autism spectrum disorder
Down syndrome
Attention deficit disorder

ABSTRACT

Findings from two studies of 11 young children with autism, Down syndrome, or attention deficit disorders investigating the effects of Popchilla, a socially interactive robot, on the children's affective behavior are reported. The children were observed under two conditions, child-toy interactions and child-robot interactions, and ratings of child interests and child emotions made for both types of affective behavior based on 10 to 15 minutes of observation of the children in each condition. Results showed that the social robot had more positive effects on child affective behavior when the speech used to engage the children in child-robot interactions was intelligible, clearly understandable, and had engaging features.

The purposes of the studies described in this research report were to determine the extent to which a socially interactive robot had positive influences on the affective behavior of young children with identified disabilities (Boser et al., 2011; Kahn, Gary, & Shen, 2013). The socially interactive robot that was the focus of investigation was Popchilla, a toy-like robot that is controlled by a practitioner or parent to engage children in robot-child interactions (Interbots, 2011). Figure 1 shows a picture of the chinchilla-looking creature. Popchilla has moveable arms, ears, mouth, and eyes (controlled by a practitioner or parent) and programmable speech output that is part of the software package (Interbots, 2013) for using the robot as part of interventions to promote the social-affective and social interactive behavior of young children with disabilities (e.g., Feil-Seifer & Mataric, 2008; Miyamoto, Lee, & Okada, 2007).

An implicit objective of using socially interactive robots with young children with disabilities, including Popchilla, is that the human-like features and qualities of social robots ought to elicit and maintain child interests and enhance positive emotions as a result of child-robot interactions (e.g., Costa et al., 2011; Ferari, Robins, & Dautenhahn, 2009; Kim et al., 2012). Research reviews of studies of socially interactive robots, however, have found little empirical evidence for the hypothesized effects of socially interactive robots on child affective behavior, not because the relationship does not exist but because few studies have actually included empirical tests of the relationships between child-robot interactions and child social-affective behavior (Diehl, Schmitt, Villano, & Crowell, 2012; Dunst, Prior, Trivette, & Hamby, 2013).

The data reported in this paper were obtained as part of two intervention studies in which the effects of Popchilla on increases in child vocalizations and joint attention were the main focus of investigation (Dunst, Prior, & Trivette, 2012). We collected, as part of those studies, measures of child affect during children's interactions with a favorite or preferred toy and interactions with Popchilla. Ratings of two dimensions of child affect (interests and emotions) were made of child behavior during the two different interactive conditions (Baker, Koegel, & Koegel, 1998).

The focus of analysis in both studies was the effects

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Figure 1. **The toy-like social robot that was used in the studies of the effects of a socially interactive robot on child affective behavior.**

of Popchilla on the children's affective behavior during child interactions with the robot compared to child interactions with a favorite or preferred toy. The study was conducted as part of a line of research investigating different features and qualities of socially interactive robots and the use of social robots as part of interventions to enhance and promote child social-communicative behavior and consequences (Dunst et al., 2012; Dunst, Trivette, Prior, & Hamby, 2013b; Dunst, Trivette, Prior, Hamby, & Embler, 2013c).

METHOD

Participants

The participants in the two studies described in this research report were 11 children with identified disabilities between 18 and 80 months of age (Mean = 46, SD = 17). The children's mental (developmental) ages ranged between 19 and 75 months of age (M = 37, SD = 16).

The six children in Study 1 were diagnosed with autism (N = 5) or Down syndrome (N = 1). The five children in Study 2 were diagnosed with autism (N = 2), attention deficit disorders (N = 2), or Down syndrome (N = 1). The children were all assessed using the *Childhood Autism Rating Scale* (Schopler, Van Bourgondien, Wellman, & Love, 2010). Three of the children with autism had scores indicative of severe symptoms of autism spectrum disorders, three children with autism had scores indicative of mild-to-moderate symptoms of autism spectrum disorders, and one child with a diagnosis of autism had a score indicative of borderline symptoms of autism. None of the four children with diagnoses other than autism had scores indicative of autism spectrum disorders.

Child Affect Rating Scale

The two item rating scale developed by Baker et al. (1998) was used to assess child affect. The two items assessed child interests and child emotions. Each item was rated on a 6-point scale ranging from zero to five. The child interests item indicators ranged from disinterested to interested and the child emotions item ranged from unhappy to happy. The scale items and criteria for each of the 6-point ratings are shown in Table 1.

Procedure

Each child was observed for 10 to 15 minutes interacting with a favorite or preferred toy and for the same amount of time interacting with Popchilla during the intervention phase of the studies. The toy that was the focus of child-toy play was identified by the children's parents or by each child's attachment to a toy based on observations prior to the experimental sessions. The child-robot interactions involved investigator-facilitated robot interactions with each child using the programmable speech included as part of the robot software package together with arm, ear, mouth, and eye movements accompanying the speech. The particular words, songs, phrases, and other types of speech available to the investigators during the intervention phase of Study 1 are listed in Appendix A. The particular speech used with each child was individualized based on observations prior to the study and reports of each child's preferences by the children's parents.

Observations during and feedback from Study 1 indicated that the clarity of speech was often unintelligible and proved to be confusing to some children. We also found that the use of the programmable speech, to a large degree, did not have characteristics that would likely promote child joint attention or elicit child-initiated interactions. As a result, we had a professional child actor rerecord the same words, phrases, and songs to improve clarity and intelligibility for use in Study 2. We also added words and phrases that were more likely to promote child-robot and child-robot-adult interactions and enhance child engagement in joint attention episodes with the robot and each child's parents. Appendix B includes the list of words, phrases, songs, and other speech used in Study 2.

Method of Analysis

Matched paired *t*-tests for between condition differences (toy vs. robot) and Cohen's *d* effect sizes for the

Table 1
Rating Scales for Assessing Child Affective Behavior During Interactions with Preferred Toys and Popchilla

Child interests		
Disinterested	Neutral interest	Interested
Child looks bored, noninvolved, not curious or eager to continue activity. May yawn or try to avoid the situations. Spends much time looking around and not attending to talk. If child does respond, may be long response latency (Score 0 or 1, depending on extent of disinterest.)	Neither particularly interested nor disinterested. Child seems to passively accept situation. Doesn't rebel but is not eager to continue. (Score 2 or 3, depending on extent of interest.)	Attends readily to task, responds readily and willingly. Child is alert and involved in activity. (Score 4 or 5, depending on level of alertness and involvement.)
0 1	2 3	4 5

Child emotions		
Unhappy	Neutral	Happy
Cries, pouts, tantrums, appears to be sad, angry, or frustrated. Child seems not to be enjoying self. (Score 0 or 1, depending on extent of unhappiness.)	Doesn't appear to be decidedly happy or particularly unhappy. May smile or frown occasionally but overall, seems rather neutral in this situation. (Score 2 or 3, depending on extent of happiness.)	Smiles, laughs appropriately. Seems to be enjoying self. (Score 4 or 5, depending on extent of enjoyment.
0 1	2 3	4 5

SOURCE: Baker, M. J., Koegel, R. L., & Koegel, L. K. (1998). Increasing the social behavior of young children with autism using their obsessive behaviors. *Journal of the Association for Persons with Severe Handicaps*, 23, 300-308.

mean differences on the child interests and child emotions subscale items for the two contrasting interactional episodes were used to evaluate the effects of the social robot and preferred toys on child affect. Cohen's *d* was computed as the differences in the mean scores for the toy and robot conditions divided by the pooled standard deviation for the two mean scores (Dunst & Hamby, 2012).

RESULTS

Study 1

Figure 2 shows the means and standard deviations for the child affect ratings for the children's interactions with a preferred toy and Popchilla in Study 1. Neither the *t*-test results nor the effect sizes for the child interests, $t(5) = .20$, $p = .85$, $d = .13$, or child emotions, $t(5) = .22$, $p = .83$, $d = .13$, subscale scores indicated a differential effect for the child-robot interactions. However, as we indicated above, the lack of clarity, intelligibility, engaging features of the speech included as part of the Popchilla software package were hypothesized to be a factor that might account for the lack of a robot influence on child affect.

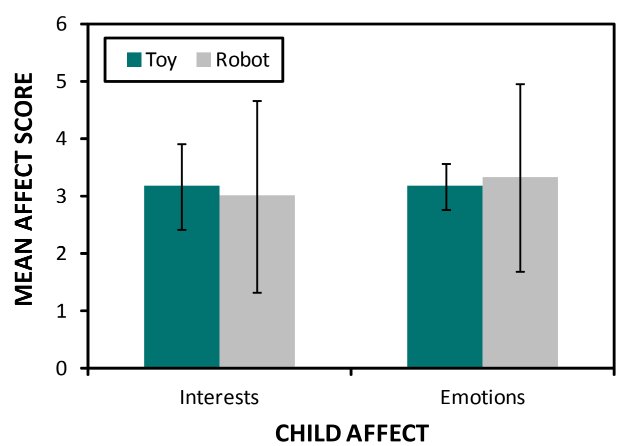

***Figure 2.* Means and standard deviations for the two child affect ratings for child-toy and child-robot interactions in Study 1.**

Study 2

The means and standard deviations for the child affect ratings for the child-toy and child-robot interactions for the participants in Study 2 are shown in Figure 3.

Both the *t*-test results and effect sizes for the child interests, $t(4) = 3.65$, $p = .022$, $d = 2.70$, and child emotions, $t(4) = 3.50$, $p = .025$, $d = 2.22$, subscale scores indicated that child-robot interactions had a more positive effect on child social-emotional behavior compared to child-toy interactions. This was attributed, to a large degree, to the clarity and intelligibility of the speech as a result of having that speech professionally recorded for the second study as well as the addition of more engaging words, phrases, songs, and other robot-produced speech.

DISCUSSION

Results indicated that Popchilla had positive effects on the children's affective behavior when the speech used to engage the children in robot-child interactions was intelligible, clearly understandable, and engaging. This was discerned by the fact that the speech included as part of the Popchilla software package used in Study 1 not only had no positive effects on child affective behavior but also was often confusing and disconcerting to the children. In contrast, the professionally recorded speech used in Study 2 had positive behavior-enhancing effects on child interests and emotions. Observations of the children's responses in both studies, as well as parents' comments and feedback, led us to conclude that in addition to the highly engaging human-like features of Popchilla (Dunst et al., 2013b), the speech used to engage the children in child-robot interactions also proved to be an important factor accounting for the effectiveness of child-robot interactions if those interactions were likely to have positive influences on child affective behavior.

Findings from our study are consistent with the hypothesized relationship between socially interactive robots and child social behavior (e.g., Boser et al., 2011; Kozima & Nakagawa, 2006). The majority of socially interactive robot studies to date, however, have been either case studies or case reports (e.g., Giullian et al., 2010; Robins, Dautenhahn, te Boekhorst, & Billard, 2005; Schulmeister, Wiberg, Adams, Harbottle, & Cook, 2006) of the behavior of children during observations of child-robot interactions (see Kim et al., 2012, for an exception). The study reported in this paper included an empirical test of the influence of a social robot on child affective behavior using effect sizes for between condition differences as the metric for evaluating the behavior-enhancing consequences of social robot features and characteristics. This type of between condition analysis has been used in other studies we have conducted for evaluating the conditions under which different kinds of interventions and environmental conditions are associated with differences or changes in child social-emotional behavior (e.g., Dunst, Raab, Trivette et al., 2007; Dunst et al., 2010; Dunst, Raab, Wilson, & Parkey, 2007; Raab, Dunst, Wilson, & Parkey, 2009).

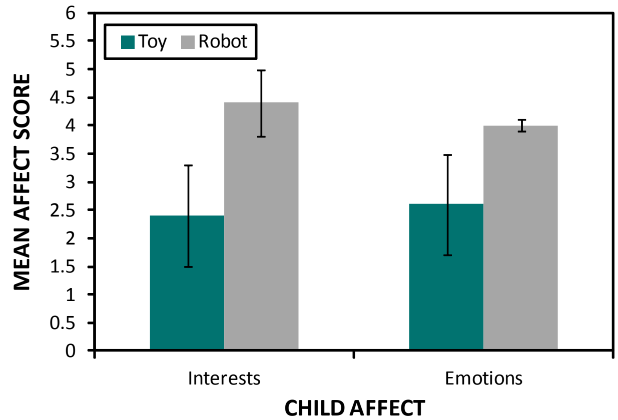

Figure 3. **Means and standard deviations for the two child affect ratings for child-toy and child-robot interactions in Study 2.**

Results from two previously completed studies of four different socially interactive robots (Dautenhahn et al., 2009; Interbots, 2011; Kozima, Michalowski, & Nakagawa, 2009; Lathan, Brisben, & Safos, 2005) were used to select Popchilla as the robot-of-choice for use in other studies of the effects of this socially interactive robot on child social-communicative behavior. Results from these previously completed studies indicated that parents considered toy-like robots as most appropriate for use with young children with disabilities (Dunst et al., 2013c), and that Popchilla was the preferred toy-like robot because of its human-like and highly engaging features (Dunst et al., 2013b). These findings, together with those reported in this paper, helped identify the conditions under which Popchilla is most likely to have optimal child benefits, and led us to evaluate the effects of Popchilla on changes and improvements in child social behavior as part of intervention studies of young children with disabilities. This included, but was not limited to, the clarity and intelligibility of speech used to have Popchilla engage young children with disabilities in child-robot interactions and the effects of those interactions on child social-emotional behavior.

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Appendix A

Popchilla World Software Speech Used in Study 1

Sounds and Words	Phrases	Songs and Rhymes[a]
Aaah!	Can you do what I say?	ABCs song
Again!	Clap your hands	BINGO was his name
Awww	Do what I do	Do your ears hang low?
Blpblpblpb	Don’t like	Happy and you know it
Bye	Don’t stop	Head, shoulders, knees and toes
Dance!	Feed me	Hokey pokey
Down	Follow me	Itsy bitsy spider
Ears	Good job	Mary had a little lamb
Eyes	Guess how I feel	Ring around the rosies
Foot	Hehehe, that tickles!	Twinkle twinkle little star
Gggah!	How are you today?	Would you like to hear a song?
Good	How do I feel?	
Goodbye	How do you feel?	
Gross!	I don’t like that	
Ha, ha, ha (laughing)	I feel _____	
Head	I like that	
He, he, he	I’m hungry	
Hello	I’m Popchilla	
Hungry	I’m sorry	
Hi	I want _____	
La, la, la	Jump up and down	
Name?	Keep clapping	
No	Keep dancing	
Nomnomnom	Keep jumping	
Oooo	Keep sitting	
Ououu	Keep standing	
Pbfft	Let’s be _____	
Please	Let’s do it again	
Right	Let’s make silly noises	
Sing	Let’s play a game	
Sorry	Look at me	
Surprised	Look down	
Tail	Look left	
Tummy	Look right	
Uh oh!	Look up	
Up	One more time	
Wheee!	Please stop	

Appendix A, continued.

Sounds and Words	**Phrases**	**Songs and Rhymes**[a]
Yay	Raise your arm	
Yaaay!	Raise your left arm	
Yummy	Raise your right arm	
	Right arm	
	Right eye	
	Right foot	
	Sit down	
	Something blue	
	Something green	
	Something orange	
	Something purple	
	Something red	
	Something yellow	
	Stand up	
	Stomp your feet	
	Stop that	
	Thank you	
	That hurts	
	That’s gross	
	That’s my _____	
	That’s silly	
	That was fun!	
	Touch my _____	
	You did great	
	You look _____	
	You’re welcome	
	What’s your name?	
	Will you feed me?	
	Will you pet me?	
	Will you scratch my ears?	
	Will you tickle my belly?	
	Would you like to hear a song?	

[a] The lyrics for each of the songs and rhymes are included as part of the software package.

Appendix B

Professionally Recorded Sounds and Speech Used in Study 2

Sounds and Words	Phrases	Songs and Rhymes[a]
Great!	Can you do this?	A Peanut Sat
Ha, ha, ha (laughing)	Can you do this? (raises left arm)	Do you want me to sing more?
Mmmmm	Can you do this? (raises right arm)	Down By the Bay
Wheee...wheee!	Can you do this? (raises both arms)	Hooorrrayyy!!!! (music and dance)
Yay	Can you do it again?	If You're Happy and You Know It
Yeh, yeh	Can you give it to mommy?	Itsy Bitsy Spider
	Can you give it to daddy?	Mother Goony Bird
	Can you move your head?	Twink-A-Link
	Can you put the hat on?	
	Can you shake your arms?	
	Can you show mommy a happy face?	
	Dance with me	
	Do you want to play?	
	Do you want to sing?	
	Give some to mommy/daddy	
	Give the ball to daddy	
	Give the ball to mommy	
	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	
	Look at the block	
	Look at the book	

Appendix B, continued.

Sounds and Words	Phrases	Songs and Rhymes[a]
	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 my nose	
	Roll me the ball	
	Roll the truck to me	
	Show daddy	
	Show me the book	
	Show me the doggy	
	Show me where the ball is	
	Show mommy	
	Sing with me	
	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 lyrics for each of the songs and rhymes are included as part of the software package.