Effect of a Child-Controlled Robot on Mother's Communicative Dominance during Play Interaction with a Child with Cerebral Palsy: a Case Study

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Abstract

Children who have severe physical disabilities often have great difficulty interacting and learning through play, and their expressive language is commonly limited. During play, mothers are frequently more directive in their interaction with children with disabilities. This might change if the child has more control over the environment. Research on the use of robots during play has shown that children with severe physical disabilities, limited fine motor abilities, and limited expressive language, vocalize more both during and after play interaction with a robot.

This study examined the effect of the use of a child-controlled robot on maternal communicative dominance in the communication between a mother and her child with cerebral palsy. Using video recorded free-play sessions collected in a previous project, we coded the communicative functions that occurred between the mother and child during play for two conditions: the first with only the child's toys, and the other with both the child's toys and a robot. Results showed that while the mother decreased her use of Yes/No Questions and increased her use of Open Ended Questions as expected, there was very little overall change in her use of Choice Questions, Direction of Attention, and Direction of Action. The child did not increase the frequency of her overall communication. The results of this study indicated that the presence of a child-control robot slightly decreased maternal communicative dominance.

Introduction

Cerebral palsy is the result of a lesion or injury in the brain that occurs from before birth to age two (Krigger, 2006). It is characterized by motor impairment (Falkman, Sandberg, & Hjelmquist, 2002). Some children with cerebral palsy have severe communication difficulties due to muscle weakness related to the speech system resulting in unclear speech (Pennington, 2008). However these children's communication difficulties may not be limited solely by muscle weakness in the speech system, but due to limited opportunities to communicate. Young children with limited mobility are highly dependent on their primary caregiver to provide for their needs. Both motor and communication limitations tend to lead to children's mothers taking on a more dominant role in communication exchanges (Pennington & McConachie, 1999). This in turn further limits the development of the children's communication skills.

Maternal communicative dominance is high when children have severe physical, communication, and cognitive disability, for example, according to Pennington and McConachie (1999), mothers of severely disabled children often used commands, requests for attention, and asked many questions that directed the interaction. The authors pointed out that this type of interaction is not beneficial for cognitive and communication development in children. Communication patterns that are learned in early childhood are 'fossilized' throughout later childhood, (Pennington & McConachie 1999). Meaning if a child learns a passive and responsive form of communication early on, this will be the pattern of communication that the child will have during his or her elementary years. Pennington and McConachie also found that the mothers took more turns than the children during the interactions. When the mothers

dominate the conversation and the children do not have an equal number of turns in an interaction, the children will then learn this pattern of communication and will have fewer opportunities to initiate and develop their communication skills.

Another study compared levels of conversational dominance when children with speech/language impairment communicated with a parent, peer, and clinician (Hansson et al., 2000). The study showed that in conversations with adults, the adults would dominate the conversation, whereas interaction with peers showed more equal turn-taking between the children and their peers.

Just as speech difficulties lead to limited language development, physical disabilities result in difficulties with manipulation of objects that affect learning of skills (Musselwhite, 1986). A review of several robot studies by Cook, Adams, Encarnacao, and Alvarez (2012) summarized that child-controlled Lego robots were effective for augmenting manipulation for children with limited mobility, allowing them to explore and interact with their physical environment. Two pilot studies have been carried out that began to investigate the effect of child-controlled robot manipulation on mother's dominance during free play. One was carried out in Spanish, and the other in English. The main variable of interest in the pilot studies was the child's playfulness, but the investigators noted the mother's behavior seemed less directive when the robot was present. A video analysis of the Spanish mother-child dyad revealed that the mother's communication style changed with the introduction of the robot during play (Rios Rincon, Sirard, Wainer, & Adams, 2013). The current study examined the effect of the use of a child-controlled robot on maternal communicative dominance in the communication between a

mother and her child with cerebral palsy from videos of the English speaking pilot study (Rios Rincon, Adams, Magill-Evans, & Cook, 2013). It was hypothesized that the use of a robot would reduce the mother's communicative dominance and increase the child's participation.

Methods

Participants

The participants in this study included a girl aged 4 years and 7 months, diagnosed with cerebral palsy with spastic quadriplegia, and her mother. We will call the child Jean in this study, which is not her real name. Interactions between the child and the mother were conducted in English, which was the language spoken in their home in Alberta, Canada.

Jean was able to initiate activities and games during free play. Her mother reported that she tended to play with the same games/toys in the same manner. Also, she could only maintain her attention and interest in an activity/game for a short period of time (Rios-Rincon, Adams, et al., 2013).

Jean's expressive communication during play sessions mainly consisted of gestures, such as facial expressions (e.g. making eye contact and smiling at mother) and manipulation of the toys around her (e.g. pulling a toy blanket towards her or pushing a toy walker away). She was able to say "yes" or "no" in response to yes-no questions and used a verbal expressive repertoire that included vocalizations (e.g. "uhhh", "aahhh") and open syllable approximations of words (e.g. /mo/ for "more", /wə/ for "walk") to comment, request, or answer questions during play. Her mother seemed to understand most of her words, and she could sometimes be understood by unfamiliar listeners (i.e. the researcher present: Rios Rincon). Jean appeared to

understand her mother throughout the play sessions. She was able to follow 2-step directions and demonstrated understanding by responding to her mother's questions appropriately (e.g. when asked a Choice Question, she chose one of the objects presented in the question.) Information was not available on whether Jean had received treatment from a speech-language pathologist. She was not using any communication devices during the time of the study.

Jean had limited mobility in her legs, but was able to sit upright on her own and to crawl short distances very slowly (Rios Rincon, Adams, et al., 2013). She had some mobility in her arms and hands as demonstrated by her ability to grasp and reach for objects as well as press the switches for controlling the robots. According to the Gross Motor Function Classification System (GMFCS) (Palisano et al., 1997), her gross motor skills were at a Level IV for her age and according to the Manual Ability Classification System (MACS) (Eliasson et al., 2006), she was at Level IV. These ratings showed that she had limited motor skills and needed assistance in terms of handling and manipulating tools and objects.

Jean's cognitive age was lower than 3 years, according to the Pictorial Test of Intelligence (PTI-2) (French, 2001). Her vision was corrected with glasses. There were no concerns about her hearing.

Materials

The materials for the study included a range of toys provided by the participants (see Appendix A), a Lego MindStorms ® "roverbot" vehicle with a scoop in front, and an adapted Lego robot infrared controller operated through three switches. The switches made the robot go forward, turn left and turn right.

Procedure

Eight sessions were videotaped over a total of five weeks with the child and her mother in their home. The eight sessions were divided into two phases: Baseline (No Robot condition) and Intervention (Robot condition). Baseline sessions were ended when playfulness as measured by the Test of Playfulness was stable (Bundy, 2010).

Baseline. The Baseline phase consisted of four sessions conducted twice a week over two weeks. Each session was 15 minutes long, and consisted of Jean and her mother playing in their natural home environment. Each toy was one meter away from Jean at the start of the sessions. Jean and her mother were given instructions to play with the toys as they typically would.

Training. After the Baseline sessions ended, the researcher trained Jean to use the robot using a previous protocol, e.g. the children learned each robot command in turn as they moved the robot to knock over blocks (Poletz, Encarnação, Adams, & Cook, 2010). Jean was trained to move the robot forward and to turn it left or right by pushing three corresponding switches. The training period lasted three sessions within a span of one week.

Intervention. The Intervention phase followed the training period, and consisted of four sessions conducted twice a week over two weeks. Each session was 15 minutes long. The Lego robot was available, along with the same toys from the Baseline sessions. Jean and her mother were instructed to play as they typically would, but with the presence of the robot as one of the options for Jean.

Data collection and analysis

The variables of interest for this study and these participants were based on a coding system developed by Rios Rincon, Sirard, et al. (2013). Their system was developed from that of Clarke and Kirton (2003), but was streamlined and revised to focus on maternal conversational dominance. Clarke and Kirton's study investigated communicative interactions between children with disabilities and their peers. Rios Rincon, Sirard, Wainer and Adams' study focused on analyzing communicative interactions between a mother and her child with severe motor and communication difficulties.

In Clarke and Kirton's (2003) article, a communicative function was defined as the purpose of a communicative act. Rios Rincon, Sirard, et al. (2013) focused on Clarke and Kirton's codes that measured directiveness. These included Request for Joint Attention, Request for Object/Action, and Request for Information. These codes were renamed and the definitions made more specific in order to fit the purposes of their study and analysis. The resulting codes used to analyze the communicative dominance of the mother's utterances were:

Direction of Attention (replacing Request for Joint Attention);

Direction of Action (replacing Request for Object/Action); and

Request for Information was subdivided into two codes:

Open-ended Questions

Yes/No Questions.

In the Rios Rincon, Sirard, et al. (2013) study, choice questions were categorized as Open-ended Questions, which were defined as questions that could not be answered with either a yes or no. However, in the present study, Jean's mother frequently posed choice questions, thus the decision was made to establish choice questions as its own question type. The child's communication was coded as either Vocalization (i.e. non-speech communicative sounds that may express emotion or intent) or Verbalization. (i.e. meaningful speech, such as a word).

These were the changes expected for each variable from the No Robot to the Robot condition (i.e., those that would indicate that the mother was less directive when the robot was present):

- Decrease in Direction of Attention, Direction of Action, Yes/No Questions, and Choice Questions
- Increase in Open-Ended Questions
- Increase in the child's Vocalizations and Verbalizations

To code the videos of the sessions, they were first imported into Morae software. All instances of communication (gestures, verbalizations, and vocalizations), hereafter referred to as 'utterances' from both participants within the video segment were flagged (time stamped) and assigned a label of either 'gesture', 'verbalization', or 'vocalization' using Morae Manager. These flagged times and labels were exported to Microsoft Excel to be transcribed and coded separately.

The authors both coded the videos, and were calibrated using the following process. Video clips of Jean and her mother in free play sessions recorded before the Baseline phrase were used. Three inter-rater reliability ratings were calculated using Clarke and Kirton's codes: the mother's and child's utterances together, only the mother's utterances, and only the child's utterances. There was a 60% agreement when considering both Jean and her mother's utterances, 76% agreement when looking at solely the mother's utterances, and 18% agreement in coding Jean's utterances. Hallgren (2012), considered reliability of 41%-60% as moderate agreement, 61-80% as substantial agreement and reliability of 81-100% as almost perfect to perfect agreement, while anything below 20% was considered in slight agreement. According to Hallgren's classification, the researchers' inter-rater reliability when using the Clarke and Kirton (2003) codes was in moderate agreement for both the child and the mother's utterances combined, in substantial agreement for solely the mother's utterances, and in slight agreement for solely the child's utterances.

After discussing the coding discrepancies of Jean's utterances, the researchers deemed Jean's communicative functions too difficult to interpret for the purposes of this paper, since many of her utterances were vocalizations and verbalizations that were unintelligible. The authors decided to focus on coding the communicative functions of the mother, while simply counting the total number of Jean's utterances and coding them as either Vocalizations or Verbalizations. An increase in the total number of Jean's utterances would indicate an increase in communicative intent regardless of the type of communicative mode (Vocalization or Verbalization). Inter-rater reliability for counting the total number of utterances and determining whether they were Vocalizations or Verbalizations was 100%.

One No Robot and one Robot session were chosen for analysis. These sessions were chosen because they had the highest Test of Playfulness score in the four No Robot and four Robot sessions (Bundy, 2010). The videos were imported into Morae. Then five-minute segments were selected from each No Robot and Robot video using a random number generator. The utterances were flagged using Morae. These were then exported to Excel for transcription and coding. Using Excel, Author 1 of this paper transcribed all of the mother and child's vocalizations, actions, and verbalizations within the five-minute clips for both No Robot and Robot videos. The same author then coded all adult verbalizations in the transcription into the two Direction Types (Direction of Attention and Direction of Action) and the three Question Types: (Yes/No Question, Open-ended Question, and Choice Question). All child utterances were coded as either Vocalization or Verbalization. To check reliability of the coding, Author 2 of this paper then coded a randomly chosen one-minute clip (20% of five minutes) from both No Robot and Robot videos. Table 1 shows the inter-rater reliability for the adult utterances and the child utterances in the No Robot condition and the Robot condition. Based on Hallgren (2012), inter-rater reliability for these codes was in substantial agreement for the mother's utterances and in perfect agreement for the child's utterances.

Table 1: Inter-rater Reliability

	NO ROBOT	**ROBOT**
Adult	63.64%	66.67%
Child	100.00%	100.00%

Microsoft Excel was used for analysing the data. The frequency of Direction of Attention, Direction of Action, and each Question Type was tallied for all adult utterances. Then the percentage was calculated for each communicative function: each occurrence of Direction of Attention was compared to the total occurrences of Direction of Attention and Direction of Action; Direction of Action was also compared to the total occurrences of Direction of Attention and Direction of Action; each Question Type was compared to the total of all Question Types. The child's Vocalizations or Verbalizations were also tallied.

Results

Direction of Attention and Direction of Action Statements

Table 2 shows the absolute number, rate, and percentage of the functions Direction of Attention and Direction of Action in both the No Robot and Robot Conditions, as well as the change in use of Direction of Attention and Direction of Action between the two conditions.

Table 2: Direction of Attention and Direction of Action in the No Robot and Robot Conditions.

	NO ROBOT			**ROBOT**				
	Absolute Number	**Rate (per min)**	**Percentage**	**Absolute Number**	**Rate (per min)**	**Percentage**	**Change in rate (Robot- No Robot)**	**Percent Change**
Direction of Attention	1	0.2	5.56%	1	0.2	8.33%	0.0	+2.77%
Direction of Action	17	3.4	94.44%	11	2.2	91.67%	-1.2	-2.77%
Directions-Total	18	3.6	100.00%	12	2.4	100.00%	-1.2	0.00%

Questions

Table 3 shows the absolute number, rate, and percentage of Yes/No, Choice, and Open-Ended Questions in both the No Robot and Robot Conditions, as well as the change in question type between the two conditions.

Table 3: *Yes/No Questions, Choice Questions, and Open-Ended Questions in Each Condition*

	NO ROBOT			**ROBOT**				
	Absolute Number	**Rate (per min)**	**Percentage**	**Absolute Number**	**Rate (per min)**	**Percentage**	**Change in rate (Robot- No Robot)**	**Percent Change**
Yes/No Question	24	4.8	64.86%	15	3.0	45.45%	-1.8	-19.41%
Choice Question	3	0.6	8.11%	4	0.8	12.12%	+0.2	+4.01%
Open Ended Question	2	2.0	27.03%	14	2.8	42.42	+0.8	+15.39%
Questions-Total	29	7.4	100.00%	33	6.6	100.00%	-0.8	+38.81%

Verbal Utterances Made by the Child

Table 4 shows the absolute number and rate of verbal utterances made by the child in the No Robot and Robot condition, as well as the change between the two conditions.

Table 4: *Absolute Number and Rate of Vocalizations and Verbalizations Made by the Child in the No Robot and Robot Conditions.*

	NO ROBOT		ROBOT			
	Absolute Number	**Rate (per min)**	**Absolute Number**	**Rate (per min)**	**Change in rate (Robot-No Robot)**	**Percent Change**
Child Vocalizations	25	5.0	20	4.0	-1.0	-80.0%
Child Verbalizations	7	1.4	2	0.4	-1.0	-28.6

Discussion

It was expected that with the use of a robot during the mother-child interaction, overall maternal communicative dominance would decrease and the child's participation would increase. Specifically, Direction of Attention, Direction of Action, Yes/No Questions, and Choice Questions were expected to decrease; the use of Open-Ended Questions was expected to increase. Likewise, the child's frequency of Vocalizations and Verbalizations were expected to increase. As can be seen in Tables 5 and 6, the results were not always as expected. Table 5 shows the Measured Percent Change in the mother's use of Direction of Attention and Direction of Action.

Table 5: *Expected Direction of Change and Measured Percent Change in Direction of Attention and Direction of Action*

	Expected Direction of Change	**Measured Percent Change**
Direction of Attention	Decrease	+2.77%
Direction of Action	Decrease	-2.77%

Mother's Direction of Attention and Direction of Action. The change in the mother's use of Direction of Attention and Direction of Action was very small overall, and it is difficult to come to any conclusions based on such small changes. In both the No Robot and Robot conditions, the dyad engaged in familiar play routines with familiar communication patterns with Jean's own familiar toys. Since the choice of toys and interaction during play was similar in both conditions, this may have contributed to the similarity of the mother's statements with regards to directing the child's actions.

Table 6: *Expected Direction of Change and Measured Percent Change in Yes/No, Choice, and Open-Ended Questions*

	Expected Direction of Change	**Measured Percent Change**
Yes/No Question	Decrease	-19.41%
Choice Question	Decrease	+4.01%
Open Ended Question	Increase	+15.39%

Mother's Questions. Analysis of the mother's questions indicated an overall decrease in maternal conversational dominance. Table 6 shows the Measured Percent Change in her use of questions. The novelty of the robot may have encouraged the mother to use more Open-Ended Questions (e.g. Where do we drive him? What do we do to drive the robot?).

Contrary to what was expected, the mother used Choice Questions *more* frequently in the Robot condition than in the No Robot condition (increase of 4.01%). In this study, and for children with limited communication like Jean, choice questions could be considered *less* directive. It is common for parents of children with severe communication difficulties to be taught the strategy of giving their children choices. For respondents with very limited communication ability, Choice Questions could have low directiveness, that is, a few choices present more opportunities to communicate for someone with severe communication difficulties than no opportunities to communicate at all. For example "Would you like to play with Ernie or the Robot?" (Choice Question) gives the child more opportunities to communicate than "Would you like to play with Ernie?" (Yes/No Question).

Table 7: *Expected Direction of Change and Measured Percent Change in Absolute Number and Rate of Vocalizations and Verbalizations Made by the Child.*

	Expected Direction of Change	Measured Percent Change
Child Vocalizations	Increase	-80.0%
Child Verbalizations	Increase	-28.6

Child. The child's total number of utterances actually decreased in the Robot condition. Table 7 shows the decrease in the child's vocalizations and verbalizations. This data would suggest an increase in maternal dominance; however, there are several factors to consider. Jean engaged in different activities in each condition. It seems that the activities she chose in the Robot session involved less turn-taking interaction than those she chose in the No Robot session. In the No Robot condition, activities such as looking at the book allowed more verbalization and vocalization for Jean; whereas, in the Robot session, the activities (e.g. Ernie and the walker, Fizzle Pop, Robot) encouraged more physical actions and thus demanded less spoken communicative interaction.

Robot control issues. The decrease of the frequency of her vocalizations and verbalizations could be due to the robot being too hard for her to control. Jean's cognitive age was lower than 3 years, according to the Pictorial Test of Intelligence (PTI-2) (French, 2001). Learning to control the robot may have been too difficult for Jean. Poletz, Encarnação, Adams, and Cook (2010) have shown that pressing the switches in sequence is required to control the

robot and only 25% of 3-year olds are able to sequence in order to control the robots successfully. Jean may have been less inclined to play with the robot because it was challenging. During the interaction when the robot was present, she did not interact with the robot much. Only 28% of the time during the Robot condition was spent interacting with the robot. She only tapped the robot switch once and in the end moved away from the robot. Children with motor impairment often persist for shorter amounts of time and prefer less challenging activities than able-bodies children (Jennings, Connors & Stegmann, 1988). In addition, Jean liked to play with the same familiar toys in the same manner, so she may have found the robot less attractive since it was less familiar than her own toys.

Comparing Results to Previous Study. Table 8 shows the direction of change in Direction of Attention, Direction of Action, Yes/No Questions, Choice Questions, and Open-Ended Questions from the No Robot to Robot Condition for the current study and the previous Spanish study by Rios Rincon, Sirard, et al. (2013).

Table 8: *Comparing Differences in Change in Maternal Communicative Directiveness Variables in Current Study versus previous Spanish Study*

		CURRENT STUDY	**RIOS RINCON et al. (2013) STUDY**
	Expected Direction of Change		
Direction of Attention	Decrease	Slight Increase	Decrease
Direction of Action	Decrease	Slight Decrease	Increase
Yes/No Questions	Decrease	Decrease	Increase
Choice Questions	Decrease	Increase	n/a
Open-Ended Questions	Increase	Increase	Decrease

Table 8 shows that the results are inconsistent between this study and the Rios Rincon, Sirard, et al. (2013) study. They reported that the interaction between mother and child was more reciprocal during the Robot condition than the No Robot condition. This implied a decrease in maternal communicative dominance, as the mother and child participated more equally in the Robot condition than in the No Robot condition. A count of the number of turns was not taken in the current study; however, a count might also have shown a decrease in the mother's number of turns and an increase in the child's number of turns. Contrary to their expectations, Direction of Action increased in the Spanish study, which may have been the result of the mother giving more instructions to the child on how to operate the robot. A similar effect was noted in the current study, where the mother spent some of her time encouraging Jean to interact with the robot.

Limitations

A major limitation was that the samples selected for analysis were quite short because of the limited amount of usable video footage available (i.e. usable video footage meant segments where Jean was visible on the screen). This was a limitation as there were few communicative utterances overall in the sample, which allowed for a small margin of error. Specifically, any change in the coding of a single utterance would have led to a large change in the percentage of that communicative function. For example, there was only one occurrence of Direction of Attention in the samples in both the No Robot and Robot conditions, which is very little data to definitively conclude whether Direction of Attention increased or decreased overall.

Future Considerations

In future studies, a number of changes could be made to increase the precision of measuring directiveness. Further subcategories could be made for Yes/No Questions since some Yes/No Questions may be more directive than others, e,g. “Do you want to play with the robot?” versus “Did you get an owie?”. Other comments could be coded, e.g. the increase in non-directive comments such as the Provision of Information may also indicate a decrease in directiveness.

It may be beneficial to count the number of turns for each participant to see if they are taking an equal or unequal number of turns as it would be one indication of the level of communicative dominance for each participant. It would also be interesting to code the number of initiations versus responses for each participant with and without the robot.

Regarding the protocol itself, instructions should be given to the mother to minimalize any additional directiveness due to the mother giving robot instructions. She should be explicitly told to allow the child to choose which toys to play with and to avoid pressuring the child to choose the robot.

The child should receive a longer training interval with the robot to become more familiar with how to control it. To minimalize the novelty of the robot in contrast to the child’s familiarity with her own toys, a completely new set of toys that does not belong to the child could be provided for both conditions. The child’s cognitive age must be considered so that the child has the ability to operate the robot successfully or the operational of the robot must be simplified.

Conclusion

The purpose of this study was to examine the effect of a robot on maternal communicative dominance between a child with cerebral palsy and her mother during free play. As expected, the mother used more Open-Ended Questions, which were less directive, with the robot present. Her use of Yes/No Questions decreased with the robot; this was also as expected. The increase in her use of Choice Questions was not expected. The change in Direction of Attention and Direction of Action was slight. The child did not communicate more frequently in the robot condition. These results demonstrate that the presence of a robot during free play may have contributed to reducing maternal communicative dominance, as far as asking questions, with this particular mother-daughter dyad, but did not influence the child's communication.

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Appendix A

Participants' Toys List

1. Blanket
2. Ernie
3. Doll chair
4. Doll's walker
5. Coin piggy bank
6. Plastic ball
7. Carriage with prince and princess
8. Hoops game thread
9. Rattle Ladybug
10. Colored computer keyboard
11. Noah's Ark with animals
12. Dinosaur
13. Panda puppet
14. Necklace
15. Games cubes to fit
16. Paper photo album of the family