Child Tutors and Robot Learners: Praising Our Way to Success

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ABSTRACT

Child-robot interaction is a rapidly growing field that helps promote creativity, critical thinking, and problem-solving skills while providing a fun and engaging learning experience. In past literature, care-receiving robots in the classroom has been shown to motivate children's prosocial behavior in care-taking and indirectly promote the concept of learning by teaching. Children are also motivated to learn when receiving social positive reinforcements. This paper seeks to address the role that social positive reinforcement by care-receiving robots has on children's engagement to teach. To address this, our experiment recruited 50 middle school children to participate in a within-subject design to teach 2 Pepper robots multiplication problems, one robot pre-programmed with verbal praise phrases and the other with no reinforcement. Trust was measured using a sub-scaled version of the 'Trust Perception Scale - HRI' survey and systematic video analysis to identify prosocial behaviors. The ANOVA test analysis supported our alternative hypothesis and showed a significant positive correlation between a care-receiving robot's social positive reinforcement and a child's prosocial behavior. We also discuss the limitations, future work, and limitations of our study to further foster children's interpersonal skills and learning development.

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1 INTRODUCTION

From robotic toys to home assistants like Alexa and social robots like Pepper and Nao, children are growing up in a world where robots are becoming increasingly prevalent in their daily lives. Robots can be programmed to facilitate learning and engage children in activities that promote social, emotional, cognitive, and physical development, and it is important to understand how children perceive and interact with them.

Trust in child-robot interaction, CRI, refers to the extent to which a child feels confident and secure in their interactions with a robot such that the robot is perceived as safe, reliable, and adaptive to the child's changing needs and preferences over time. In the field of education for CRI, the major focus has been on educational robots playing the role of human teachers or caregivers [13][12], and less on placing the robot in a role where it receives instruction or care from the children instead. This involves learning by teaching, introducing a care-receiving robot with perceived fewer abilities than the children which will induce the child's prosocial behavior, that is the motivation to help others, while also developing important interpersonal skills such as empathy, patience, communication, and leadership skills.

Positive reinforcement boosts a child's confidence and motivation to learn and grow, and robot feedback in CRI has been shown to affect children's engagement [8]. However, the concept of care-receiving robots that provide positive reinforcement has not been studied. Understanding how children react to feedback through the learning-by-teaching paradigm will help us make better-informed decisions about behavior implementations when designing educational robots

Our paper seeks to address the gap in the literature by investigating how the use of social positive reinforcement or lack thereof during the teaching process affects children's prosocial behavior in care-receiving robots. We aim to gain insight into how children engage and trust robots in the learning context of teaching a mathematical concept while receiving different types of reinforcement.

2 BACKGROUND AND RELATED WORK

In this section, we will review relevant literature on the educational method of learning by teaching, children's care-taking behaviors to care-receiving robots, social positive reinforcement, and children's prosocial behavior and trust towards robots, in both educational and non-educational settings.

2.1 Teaching Care-Receiving Robots

2.1.1 Learning by Teaching. Learning by teaching is an educational method derived from cooperative learning [2], in which a student takes on the role of a teacher to explain a concept or skill they learned to their peers. When students teach each other, they must organize their thoughts and ideas clearly and concisely, identify what is most important, and present the material efficiently. Doing so can help reinforce their own understanding and gain a deeper understanding of the subject matter [3], as well as develop important interpersonal skills such as empathy, patience, communication, and leadership skills [16]. A study investigated peer tutors' learning and found that it supports knowledge-building and integration of new and prior knowledge [17][6]. The concept had also been applied to virtual agent computers, a system to better prepare students to learn new concepts [4].

2.1.2 Care-Receiving Robots. A care-receiving robot is a robot that receives care from the people around it, used for learning support and reinforcement for children [22]. Care-receiving robots introduced to the classroom had been shown to induce children's care-taking tendencies over other toys [21]. Researchers have utilized children's natural motivation to provide care and applied them in an educational setting. By engaging in care-taking behavior towards care-receiving robots, children are able to complete tasks

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that provide indirect practice of learning by teaching. The approach has helped children learn new English verbs effectively [23] and the learning capability of the robot to improve had a great impact on children's learning ability [15].

2.2 Social Positive Reinforcement

Social positive reinforcement is using a reward to encourage behavior, including any social interactions such as smiles, tickles, high fives, and praise. It is often used in school, home, and community settings to acknowledge a child's effort and progress while encouraging them to continue exhibiting the desired behavior [24]. It also helps boost a child's self-esteem and confidence, further enhancing their motivation to learn and grow [9].

2.2.1 Verbal Praise. Verbal praise is a teaching strategy that has been shown to boost a student's confidence and motivation to learn and grow [7]. A study on preschoolers showed that informational praise (e.g., "You are pretty good at this; You really did a good job.") led to a longer subsequent desire to engage with the praised task over money or symbolic rewards [1]. Among elementary children, the frequency of praise is positively correlated with self-perceptions of ability [5]. Praise is likely to enhance intrinsic motivation, however, is dependent on the characteristics of the recipient such as age, gender, and culture [11].

2.3 Prosocial Behavior and Trust

Prosocial Behavior is defined as an action aimed to help or benefit others [10]. It is characterized by a concern for the welfare of others, a willingness to act for their benefit, and an intention to promote positive social outcomes [14]. Trust, on the other hand, is defined as the willingness of a party to be vulnerable to the outcomes of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party [25]. Trust comprises of positive expectation about the behavior of others [14]. In theory, Prosocial behavior and trust can be positively correlated because trust is often a prerequisite for engaging in prosocial behavior. One study found that children's trust in their peers was associated with their peer-reported helpfulness [18]. Another study demonstrated that a child's trust in others was linked to teacher-reported prosocial behavior [14]. In this present research, we use prosocial behavior as one of the measures of trust.

2.4 The Present Study

From past literature, reinforcement in child-robot interaction had been shown to affect children's engagement, where the robot plays the dominant role of the teacher. It is unclear whether incorporating reinforcement on the reverse role, the robot being the student and the child being the teacher, would lead to the same effect of engaging the child in the task. Children may react differently to this shift in power dynamic and we seek to explore how they can further be empowered through robot behavior implementations, in this case, social positive reinforcement through verbal praise. Integrating the three concepts of "Learning by Teaching", "Social Positive Reinforcements" and "Prosocial Behavior", this present research aims to provide insights into how care-receiving robots can help boost children's learning engagement while utilizing a more balanced interaction of verbal reinforcement.

3 HYPOTHESES

From the background section, it leads to the research question as follows: "How does a robot's social positive reinforcement affect children's prosocial behavior when teaching the robot multiplication problems?"

Null hypothesis (H0): There is no correlation between the presence of a robot's social positive reinforcement and a child's prosocial behavior.

For our first alternate hypothesis (H1): We hypothesize that there is a positive correlation between the presence of a robot's social positive reinforcement and a child's prosocial behavior. When teaching the robot, we predict that children will demonstrate higher levels of prosocial behavior interacting with the robot that gives social positive reinforcement compared to when they interact with the robot that does not give social positive reinforcement.

4 METHODOLOGY

4.1 Participants and Materials

For the participants, the study included a total of 50 children with a middle school education level, ranging from 5th to 8th grade. This age group was selected because they were deemed to have the necessary math skills, specifically multiplication, which is generally taught in 2nd grade. In order to remove the variable of gender and its potential influence on prosocial behavior, the sample was evenly divided between the 2 genders (25 boys and 25 girls). Previous research had indicated that girls tend to exhibit more prosocial behavior, so this was taken into consideration when selecting the sample for this study [14]. Overall, the sample was selected with the aim of ensuring that the participants had the necessary math skills while minimizing potential confounding variables that could affect the results.

For the human-robot interaction, we utilized the Pepper robot with pre-programmed social positive reinforcement phrases that could be turned on or off. The robot was programmed with a set of general praise phrases to use as the child teaches the robot, such as "I'm learning a lot from you", "You did a great job explaining", and "Thank you for your help!". We chose the Pepper robot because size may be a confounding variable, where smaller robots such as Cozmo may appear friendlier and children may be more willing to engage with them. By using a more adult-sized robot, we aimed to eliminate this variable in order to better observe any changes in interaction due to the robot's reinforcement.

4.2 Measures

The independent variable is the presence of social positive reinforcement from the robot and the dependent variables are trust and prosocial behavior.

To measure trust, we utilized the sub-scaled version of the "Trust Perception Scale - HRI" survey, which was developed by Kristin Schaefer [20]. The survey is a self-report measure that utilizes a likert scale, allowing for a quick quantitative analysis of trust scores. The reason we selected this survey is that it uses simpler and more straightforward phrasing and wording, making it more understandable for children compared to other surveys like the MDMT. We used the sub-scaled version of the survey, which consists of 14 questions instead of the original 40, as it is quicker and easier to administer to children. Table 4.2 shows the full version of the "Trust Perception Scale - HRI" survey, with the sub-scaled items denoted by 'b'. The overall trust score was calculated by summing each item and dividing by the total number of items (14). The higher the trust score, the higher the trust in the robot.

Prosocial behavior was measured through the analysis of video recordings. During the study, the participants' interactions with the robot were recorded, and a systematic analysis of the recordings was conducted to observe their behaviors that support prosocial behavior. The analysis involved coding for specific behaviors from the participants which included both subjective and objective data. Subjective data included the participants' body language such as smiling, eye contact and touch. Objective data included the participants' actions of offering further assistance to the robot, praising the robot for its efforts, and encouraging the robot to keep trying. The frequency and number of times that the participants engaged in these actions were also analyzed.

Table 1: "Trust Perception Scale - HRI" survey

	0 %	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100 %
What % of the time will this robot be . . .											
1. Considered part of the team	O	O	O	O	O	O	O	O	O	O	O
2. Responsible	O	O	O	O	O	O	O	O	O	O	O
3. Supportive	O	O	O	O	O	O	O	O	O	O	O
4. Incompetent[a]	O	O	O	O	O	O	O	O	O	O	O
5. Dependable[b]	O	O	O	O	O	O	O	O	O	O	O
6. Friendly	O	O	O	O	O	O	O	O	O	O	O
7. Reliable[b]	O	O	O	O	O	O	O	O	O	O	O
8. Pleasant	O	O	O	O	O	O	O	O	O	O	O
9. Unresponsive[a,b]	O	O	O	O	O	O	O	O	O	O	O
10. Autonomous	O	O	O	O	O	O	O	O	O	O	O
11. Predictable[b]	O	O	O	O	O	O	O	O	O	O	O
12. Conscious	O	O	O	O	O	O	O	O	O	O	O
13. Lifelike	O	O	O	O	O	O	O	O	O	O	O
14. A good teammate	O	O	O	O	O	O	O	O	O	O	O
15. Led astray by unexpected changes in the environment	O	O	O	O	O	O	O	O	O	O	O
What % of the time will this robot . . .											
16. Act consistently[b]	O	O	O	O	O	O	O	O	O	O	O
17. Protect people	O	O	O	O	O	O	O	O	O	O	O
18. Act as part of the team	O	O	O	O	O	O	O	O	O	O	O
19. Function successfully	O	O	O	O	O	O	O	O	O	O	O
20. Malfunction[a]	O	O	O	O	O	O	O	O	O	O	O
21. Clearly communicate	O	O	O	O	O	O	O	O	O	O	O
22. Require frequent maintenance[a]	O	O	O	O	O	O	O	O	O	O	O
23. Openly communicate	O	O	O	O	O	O	O	O	O	O	O
24. Have errors[a]	O	O	O	O	O	O	O	O	O	O	O
25. Performa a task better than a novice human user	O	O	O	O	O	O	O	O	O	O	O
26. Know the difference between friend and foe	O	O	O	O	O	O	O	O	O	O	O
27. Provide feedback[b]	O	O	O	O	O	O	O	O	O	O	O
28. Possess adequate decision-making capability	O	O	O	O	O	O	O	O	O	O	O
29. Warn people of potential risks in the environment	O	O	O	O	O	O	O	O	O	O	O
30. Meet the needs of the mission/task[b]	O	O	O	O	O	O	O	O	O	O	O
31. Provide appropriate information[b]	O	O	O	O	O	O	O	O	O	O	O
32. Communicate with people[b]	O	O	O	O	O	O	O	O	O	O	O
33. Work best with a team	O	O	O	O	O	O	O	O	O	O	O
34. Keep classified information secure	O	O	O	O	O	O	O	O	O	O	O
35. Perform exactly as instructed[b]	O	O	O	O	O	O	O	O	O	O	O
36. Make sensible decisions	O	O	O	O	O	O	O	O	O	O	O
37. Work in close proximity with people	O	O	O	O	O	O	O	O	O	O	O
38. Tell the truth	O	O	O	O	O	O	O	O	O	O	O
39. Perform many functions at one time	O	O	O	O	O	O	O	O	O	O	O
40. Follow directions[b]	O	O	O	O	O	O	O	O	O	O	O

[a]Represents the reverse coded items for scoring
[b]Represents the 14 item sub-scale items

4.3 Procedures

The study utilized a within-subject design where 50 participants were randomly assigned to two groups, A and B, with 25 participants in each group. Since participants were exposed to both robots with social positive reinforcement and without social positive reinforcement, we utilized within-subject design in order to minimize the effect that any differences in child-robot trust were not due to the order of exposure.

To assess baseline math ability, participants were first asked to answer 5 multiplication problems, ensuring that they were able to teach the robot. Next, participants taught Robot #1 the same 5 multiplication problems (the presence of social positive reinforcement depends on the group that the participant is in, as shown on table 2). After teaching the robot, participants completed the Trust Perception Scale HRI survey to measure their level of trust in Robot #1. This process was repeated for Robot #2, where participants again taught the same 5 multiplication problems and completed a survey to measure their trust in Robot #2.

Table 2: exposure of type of robot for groups A and B. SPR = social positive reinforcement.

	Robot #1	**Robot #2**
Group A	Yes SPR	No SPR
Group B	No SPR	Yes SPR

5 RESULTS AND DISCUSSION

From the surveys and video analysis, we obtained 2 data, data A contained surveys and video analysis from interacting with the robot that had social positive reinforcement and data B contained surveys and video analysis from interaction with the robot that did not have social positive reinforcement. We conducted an ANOVA (analysis of variance) to test whether there was a significant difference in trust and prosocial behavior between the two data. We first calculated the mean and standard deviation for each data on the dependent variables, trust and prosocial behavior. We then calculated the total variance across all the data and the variance within each data. The F-statistic was then calculated using these variance. The results are as follows:

5.1 Reject null hypothesis

Our calculated F-value is higher than the critical value. We reject H0 and conclude that there is a significant correlation between the presence of a robot's social positive reinforcement and a child's prosocial behavior. This conclusion supports our alternate hypothesis (H1), that there is a positive correlation between these variables. Our assumption remains and this result supports and follows our background research and prediction. This finding is significant for our research as it may have practical implications for the development of educational robots that can effectively engage with children and promote learning outcomes. While it is important to acknowledge the limitations of our study (as discussed in our limitations section), our current findings offer valuable insights into the potential benefits of using social positive reinforcement in educational robotics.

5.2 Fail to reject null hypothesis

Our calculated F-value is lower than the critical value. We fail to reject H0 and conclude that there is insufficient evidence that supports the idea that there is a significant correlation between the presence of a robot's social positive reinforcement and a child's prosocial behaviors. Our inability to reject H0 does not support our background research and prediction. However, it is important to note that several other factors may impact trust and social behavior in children beyond the scope of our study, such as cultural and social backgrounds, which we discussed in our limitations section. It is possible that these factors influenced our results and contributed to the lack of a significant correlation between the presence of a robot's social positive reinforcement and a child's prosocial behaviors. Further research that takes these factors into account may be necessary to fully understand the impact of social positive reinforcement on children's prosocial behaviors when teaching a robot.

6 CONCLUSION

6.1 Limitations

Confidence in teaching may be a confounding variable that could have affected the results of our study. Previous research has shown a positive correlation between confidence in material and participation in class [19]. Using this idea, the more confident a participant is in teaching, the more willing they are to help and showcase prosocial behavior. In our study, we utilized mathematical problems as the teaching material, which may have biased our results in favor of participants who have stronger skills in mathematics than participants who are more skilled in other areas such as science. It is important to note that other complex tasks, such as teaching a language or a musical instrument, may result in different results due to the subjective nature of those skills. This could have impacted our results, as positive social reinforcement from the robot may have less of an impact on the participants if they were not confident in their teaching abilities and did not believe the robot's praise.

It is important to recognize that there are multiple factors that could potentially impact trust and prosocial behavior in children beyond what was explored in our study. Cultural and social backgrounds, for instance, may have a role in how children perceive and interact with the robot. As technology familiarity and comfort levels can differ among children from various backgrounds, these factors could affect their trust in and willingness to engage with the robot. Additionally, variations in individual personalities could also pose as a confounding variable. For example, some children may naturally be less outgoing or less prone to overt prosocial behaviors, despite their level of trust in the robot. It is therefore necessary to acknowledge these potential limitations in our research and consider them when interpreting our findings.

6.2 Future work

There are several directions for future research in child-robot interactions. First, our study can be expanded to explore the long-term effects of positive reinforcement on child-robot interactions. This would provide insight into whether the observed increase in prosocial behavior is sustained over time and if it has a lasting impact on children's engagement with robots. Second, future studies could explore the impact of different types of positive reinforcement on child-robot trust and engagement. For example, verbal versus nonverbal positive reinforcement could be examined to determine if they have differential effects. Third, the limitations identified in our study suggest that future research can investigate the role of confidence and willingness to teach robots in prosocial behavior. Utilizing more complex and subjective concepts could provide more insight into the process of interaction with robots. Fourth, future studies can investigate the impact of children's previous experience with robots and personality traits, such as extraversion and neuroticism, on their engagement with robots. Personality traits may influence the child's preference for certain types of interactions with robots and their level of trust in the robot. These directions can further advance our understanding of child-robot interactions and inform the development of effective and engaging educational robots.

6.3 Implication

Our study shows that robots that provide positive reinforcement during learning activities can improve children's prosocial behavior. This suggests that educational robots designed to provide social positive reinforcement can potentially create more engaging and effective learning experiences for children. By incorporating positive reinforcement features, educational robots can encourage children to be more involved in problem-solving activities, social play, and household chores.

In addition to academic learning, robots that provide positive feedback and reinforcement could also help children build important social and emotional skills. For example, social play activities with a robot could help children develop communication, empathy, and cooperation skills. By teaching and playing games with a robot, children could improve their problem-solving abilities and learn how to work collaboratively. Additionally, robots could help children take on more responsibility in doing household chores, which can improve their sense of autonomy and self-efficacy.

Overall, the implications of our research suggest that educational robots with positive reinforcement features could have significant potential in creating more engaging and effective learning experiences for children, as well as fostering important social and emotional skills.

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