Studying the Effect of Perspective-Taking in Learner-Robot Interaction

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Abstract

The use of robots as peer-learner is more and more studied in human-robot interaction with co-learning interactions being complex and rich involving cognitive, affective, verbal and non-verbal processes. We propose to study the co-learner interaction with robots in the light of perspective-taking; a cognitive dimension that is important for interaction, engagement, and learning of the child. This study aims to advance our knowledge about the child's behavior during a task that requires perspective-taking and to use that knowledge in designing the robot's cognitive skills in such scenarios with children. Hence, we propose an experimental study to evaluate the effect of robot's perspective-taking behavior on the child's comprehension of the task and performance. We hypothesize that children perform the tasks better in egocentric conditions and prefer to use egocentric perspective to instruct the robot. However, they will be influenced by the robot in addressee-centric condition and will try to take the robot's perspective. Our analyses will help us to integrate a perspective-taking model in our robotic platform that can adapt its perspective according to educational or social aspect of the interaction.

***K*eywords** Perspective-Taking · Cognitive skills · Child-Robot interaction · education · Mathematics

1 Introduction

To create a successful interaction, it is essential for both parties to understand each other [1, 2]. The importance intensifies when the interaction happens within educational mediums with children involved. In a child-robot interaction scenario, one of the main responsibilities of the robot is to maintain mutual understanding between itself and the child. To maintain such an understanding, it is imperative that both parties have a grasp of each other's perspective. This arises a need to study the child's behavior in the presence of a robot in tasks requiring them to take a different perspective than themselves. To study the child's behaviors, a robot can offer valuable assistance in providing controlled perspective-taking behaviors in different conditions.

Our goal is to provide a cognitive behavioral model that adapts the robot's perspective to a perspective that can either help the child to understand the task better, or help them to develop their perspective-taking skills. For the robot to be able to adapt its perspective based on the child's perspective or requirements of the task, first we need an assessment of the child's perspective-taking abilities. To acquire such an assessment, we need to explain what do we mean by perspective-taking and why it is important.

When we discuss perspective-taking, we are talking about the ability to take another person's perspective [3]. The ability to shift one's perspective to others' perspective was considered a major breakthrough in developmental studies in social cognition by Piaget [4]. In Piaget's terminology, this is the ability to decentralize from your own point of view to a different one and to understand things from another perspective [5], [6]. A switch from "egocentric perception" to "allocentric perception" is called decentralization procedure. Taking others perspective can be a cognitive act of trying to understand them (cognitive perspective-taking) or the spatial act of trying to understand their perspective of locations (physical perspective-taking) [7]. In physical perspective-taking, we need to understand that people in different locations have distinct physical relationships with objects and each other. Which leads to the acquisition of disparate levels of information about the physical world, and at times this can be conflicting. In this case, being able to take other people's perspective can help to reduce the misunderstandings and conflicts. Specifically, this can be helpful while interacting with children. There are numerous arguments regarding children egocentric behavior in communication [5, 8, 9]. They are said to develop a representational theory of mind by the time they are 4 or 5 and understand that others can have different beliefs from their own [10].

Looking at the previous studies on perspective-taking in human-robot interaction, there is a lot of focus on the way adults perceive robots and its agency, and how perspective-taking can facilitate the execution of some tasks. For example, Lee et al.'s study shows that people make certain assumptions about the robot's knowledge, similar to their human counterparts [11]. A study by Berlin et al. demonstrates that perspective-taking plays an important role in learning within social contexts by presenting an architecture for collaborative human-robot interaction [12]. The study by Trafton et al. indicates the importance of perspective-taking in human-human interaction, draws conceptual guidelines for human-robot interaction, and demonstrates that perspective-taking plays an important role in collaborative and learning scenarios with robots [13]. On the other hand, there are more recent studies focusing on perspective-taking or emotional understanding that covers perspective-taking with children. The studies by Robins et al. and Wood et al. try to develop child-robot interaction scenarios with Autistic children to develop their visual perspective-taking skills [14, 15]. Leite et al.'s work uses the robot in interactive storytelling activities with the goal to help children building their emotional intelligence skills. The emotional intelligence skills covers the development of cognitive skills and socio-emotional abilities [16].

The answer to our questions are meant to help us in understanding the child's perspective-taking behavior in a peer-learning activity with a robot. Since our focus is on physical perspective-taking, we develop a mathematics activity with a manipulative called abacus. The activity is designed to let children practice addition and subtraction using the abacus, while being instructed or instruct the robot to solve the problems. To evaluate the effect of interaction and different conditions, we measure and analyze the children's utterances and success in solving the problems. We expect the final result help us to develop an adaptive perspective-taking behavior of the robot according to the goals of the interaction.

2 Research Questions

In the scope of this research, we are planning to cover both physical and cognitive aspects of the perspective-taking. However, we start from physical perspective-taking and move onto the cognitive or socio-emotional aspect after building our behavioral model for the physical part. Aligned with our goals, the research questions related to the first phase of our study are:

RQ1: *In a learning scenario that needs perspective-taking, which perspective children are more comfortable to take?*

RQ2: *Do children tend to constantly use egocentric perspective during the interaction or are they willing to follow their counterpart's perspective-taking behavior, even if it is against what they are more comfortable with?*

RQ3: *Do children understand the task better when the robot takes their perspective (addressee-centric) or when the robot behaves egocentrically?*

As previously explained, children tend to behave more egocentrically in younger ages. There are also studies showing gender differences in development of socio-emotional skills in early childhood, attributing better emotional development and as a result perspective-taking skills to girls. To further understand our questions, we explore the effect of different perspective-taking behaviors on children understanding and performance. To define these changes of perspective, we introduce frames of reference, which are used to explain the spatial relations in perspective-taking studies. Based on numerous experimental work done in this area, five frames of reference has been proposed [13, 6]. These frames are shown in Table 1.

Frame of reference	Origin	Example
Exocentric	World-based	move north
Egocentric	Self-based	move to the right
Addressee-centric	other-based	move to your right
Deictic	Neutral	move here [with pointing]
Object-centric	Object-based	move to the right of the table

Table 1: Different frames of reference with their examples

3 Experimental Design

When we design the flow of the study, we need to consider our expectations and hypotheses. From the educational aspect of the study, the robot and the child take turn to solve some questions. This method of interaction was selected for two reasons: first, it gives us a chance to evaluate the effect of robot's behavior on the child's and second, children engage in a self-other training [17]. In a study by Okita, it is shown that self-other training might be an effective way to help students develop metacognitive skills to self-correct and improve performance in elementary mathematics. The take turning aspect of solving the questions are letting us to study how the behavior of the robot in its turn can affect the child's behavior in their turn. As a result, based on the frames of reference introduced in Table 1, we assign three behavioral condition to the robot. These conditions are: *ambiguous*, *egocentric*, and *addressee-centric*. In *ambiguous condition*, the robot does not use any explicit frame of reference, it uses vague sentences such as "move three beads to the right". The sentence is vague in a sense that it does not explicitly mention whose right. In *egocentric condition*, the robot uses itself as the reference, hence, it produces the instructions from its own point of view. For example, it says "move four beads to my left". In *addressee-centric condition*, the robot uses the child as the reference and makes its sentences from the child's point of view, saying "move five beads to your left". The whole duration of interaction is divided into tasks with children solving the questions with instructions from the robot and vice versa. We call the tasks that the child instructing the robot as the *child-turn task* and the other ones as the *robot-turn task*. And as we explained there are three conditions assigned to the robot turn tasks.

In a between-subject experimental design, we divide the students into four groups of similar age and math knowledge. In each group, the first segment is introduction, in which the child and the robot are instructed by a facilitator on how to use the abacus and solve the questions. The next segment is a child-turn task and the child is supposed to instruct the robot in solving the questions. In these tasks, the child is provided with cards displaying the questions, the child records their own answer and the robot answers on the card after each session. In robot-turn conditions, the robot instructs the child how to solve each questions using the abacus and records their answer. What makes the groups different is the type and order of their robot-turn conditions. For example in the *Amb-Ego* group, the first robot-turn condition is ambiguous and the second one is egocentric. The groupings and the order of the experiment is shown in table 2.

Groups	Task0	Task1	Task2	Task3	Task4	Task5
Amb-Ego	Introduction	Child-turn	Robot-turn **(Ambiguous)**	Child-turn	Robot-turn **(Egocentric)**	Child-turn
Amb-Add	Introduction	Child-turn	Robot-turn **(Ambiguous)**	Child-turn	Robot-turn **(Addressee)**	Child-turn
Ego-Amb	Introduction	Child-turn	Robot-turn **(Egocentric)**	Child-turn	Robot-turn **(Ambiguous)**	Child-turn
Add-Amb	Introduction	Child-turn	Robot-turn **(Addressee)**	Child-turn	Robot-turn **(Ambiguous)**	Child-turn

Table 2: Plan of the experiment with a between-subject study Design

4 Hypotheses

The experiment grouping and order of the tasks are designed to help us test our hypotheses. The ambiguous condition is designed to analyze the child's selection between asking for clarification or carrying on with the task. In the groups *Amb-Ego* and *Amb-Add* that have the ambiguous approach first, and we are interested to see how children behave when their first interaction with the robot is ambiguous. We mainly have two expectations from them, asking for clarification or using their egocentric view to solve the questions. In this case, our hypothesis is:

> **H1:** *When the first encounter of children with the robot is ambiguous, they tend to choose their egocentric perspective to solve the questions.*

As you can see the first hypothesis does not deal with perspective-taking as much as with children's behavior in ambiguous condition. On the other hand, in the two groups of *Ego-Amb* and *Add-Amb*, the ambiguous task comes second. While we have the same two expectations from children, we have a different hypothesis for these groups. This time, we hypothesize that:

> **H2:** *When the second encounter of children with the robot is ambiguous, they tend to consider the robot's perspective-taking model from its first encounter as their frame of reference.*

This hypothesis deals with the effect of egocentric and addressee-centic conditions on the child's perception of the ambiguous condition. Needless to say, we expect some of the children ask for clarification during the ambiguous condition, either it is the first or second robot-turn task. The first two hypothesis deal with the way children comprehend the robot. Our next hypothesis is focused on how children are influenced by the robot's behavior when they produce their instructions to the robot. Consequently, we are interested to study the child's behavior in the child-turn tasks that comes after the egocentric or addressee-centric tasks. We expect children to follow the robot's example, even though it would be harder for children to behave addressee-centrically. In this case, we hypothesize:

> **H3:** *Children in the child-turn task select their egocentric or addressee-centric behavior as a function of robot's perspective in the previous task.*

5 Platform Design

In this study, we create a task that requires the child and the robot to change their perspectives in the physical world. Our motive is to discover the features that help the child to understand and perform the task better and improve the interaction quality. The two aspects we wish to develop are *cognitive* and *educational*. The cognitive aspect of the interaction translates to the robot's features and the educational aspect translates to the features of the task. The robot feature is its ability to take different perspective, change and adapt it as required. The main feature of the task is providing the possibility to use different frames of reference. And we achieve this goal by using an abacus that is positioned between the child and the robot and is used for solving addition and subtraction problems. The learning trajectories presented by Clements and Sarama is going to be devised in structuring our activity. [18]. As shown in Figure 1, we place a Wacom tablet displaying a virtual abacus developed by QML language between the child and the robot.

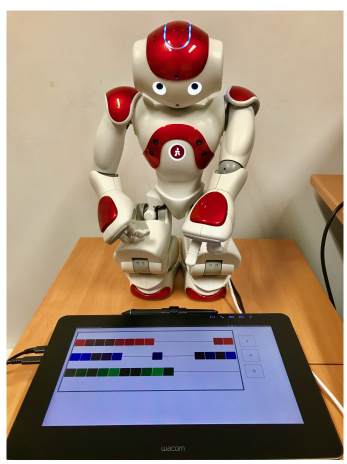

Figure 1: Child's perspective: robot interacting with the virtual abacus

6 Expectations and Conclusions

In conclusion, the work described in this paper is an on-going investigation, ready for the experimental study to be performed in elementary schools. The platform is fully autonomous, with the possibility of slight interventions from the experimenter during the experiment. After testing our hypotheses in this experiment, we are going to use our finding in developing the robot's behavioral model. And the behavioral model is going to be used to adapt the robot's behavior to the child during learning activities.

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