



“Can you teach me?” – Children teaching new words to a robot in a book reading scenario

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Abstract

In research on children’s language development, joint book reading is appreciated as being a situation beneficial for language learning. Motivated by this string of research, our aim was to explore whether the situation of joint book reading can be applied to a child–robot interaction. Before investigating whether and how this situation – when applied in child–robot interaction – can be used as a language learning scenario, the interactional requirements for a successful dialogue have to be studied. Our main aim in this paper is to present a study design for a child–robot interaction, in which a robot is introduced as a learner that acquires new color words, and the child is asked to teach the robot those words within a familiar interaction format of joint book reading. We then report the observations that we made in a single-case pilot study conducted with a 4;8-year-old child, and discuss these observations in terms of how the robot’s interactional behavior needs to be shaped to successfully participate in the situation of joint book reading.

Index Terms: child-robot interaction, joint book reading

1. Introduction

Young children learn through social interaction. Evidence shows that whereas older children can also learn words or actions from television [1]–[3], younger children do not benefit from these media [4]. Thus, they need the contingency of social interaction and the presence and support of social partners [3], [5]. Nonetheless, some studies show that technology can be useful when it is applied systematically [6]. Other information technology such as e-books are also studied and discussed in terms of its applicability in early education and its effects on learning [7], [8], but the findings seem to be mixed, as reported by [7] (also see [9]).

Research in human–robot interaction (HRI) has begun to investigate how robots can be used to improve educational performance. In fact, because robots provide “an embodiment and the ability to add social interaction to the learning context” [10, p. 1], they offer a transition from social to physical interaction. Together with the potential to serve as a partner to children [11], robots thus offer a method to support and scaffold children in their communication. Whereas developmental scientists have extensively investigated the effects of media use, research on how an interaction with a robot affects learning in children is scarce and discussed primarily within HRI. Yet, robots are showing increasing educational potential for children [12]: For example, they are used (1) as learning tools to teach mainly school-aged children natural sciences or foreign languages [13], (2) as peers to improve communication skills in children with autism spectrum disorder (e.g., [14]), or (3) they serve as tutors for health issues in clinical settings (e.g., [15]).

Those studies, in which a robot engages in social interaction with a child, mostly use imitation games as an interaction format. By an interaction format, we mean the pragmatic circumstances which are considered appropriate for an interaction. More specifically, Vollmer and colleagues [16, p. 2] define interaction format as “a pattern in verbal and non-verbal behavior involving goal-oriented actions coordinated with the interaction partner that emerges over recurrent interactions”.

An interaction format that, to our knowledge, has not been applied in child–robot interaction (cHRI) so far is that of joint book reading. Research in developmental science, however, has acknowledged this format as being very beneficial for young children’s linguistic development (e.g., [17], [18]) because it fosters joint attention [19], [20], is repeatable [21] and is an activity that children in Western cultures are usually familiar with as it draws on certain routines [18], [22]. Those routinized formats, also called ‘pragmatic frames’ [23], help children not only to participate in an interaction but also to identify a clear role that s/he can fulfill. They are routinized because their structures have become familiar to the participants – an aspect that should be considered when designing dialogue in HRI, as suggested by Steels [24]. In fact, routinized activities can become an ‘educational game’ [25] in which social interaction serves educational purposes because it systematically elicits children’s verbal knowledge.

However, before using this format for educational purposes, e.g. the acquisition of new words, we need to evaluate its applicability in a cHRI. In our cHRI study, we thus applied a language game within a book reading situation and aimed to analyze the interactional requirements for a successful dialogue. In our language game, instead of assigning the robot the role as the teacher of new words, we introduced it as being the one that should be taught new words, and therefore, assigning the role of the teacher to the child.

The idea of reversing the roles goes back to the recognition of a dialogical role being a vehicle for understanding the reciprocity of communication that was shown to improve social and communication skills in children [26], [27]. A role reversal is thus defined by the child performing “an action toward an adult in the same way that the adult performed it toward him or her” [28, p. 254]. Accordingly, for cHRI, a child performs an action towards a robot in the same way that s/he has experienced it within previous parent–child interactions. Applying role reversal in cHRI is based on the work by Tanaka and Matsuzoe [29] as well as Tanaka and Kimura [30] who proposed a novel design in cHRI enabling preschool-aged children to learn by teaching a robot rather than by being taught by a robot. Tanaka and Matsuzoe [29] aimed at promoting “children’s spontaneous learning by teaching” [29, p. 78]. The

presumed mechanisms that facilitate learning within this design are twofold according to [29]: First, instructing a robot in a particular topic is highly motivating for the children, and second, it serves as “indirect practice [...] for the children” [29, p. 80]. However, Tanaka and Matsuzoe [29] did not use a familiar interaction format in their teaching scenario. Instead, an adult experimenter had to model how to teach the robot before the children could do it on their own. By applying a familiar interaction format such as book reading, we expected that modeling the interactional behavior would not be required. Besides the two studies mentioned above [29], [30], we do not know of any study that investigated how children engage in cHRI when interactional roles are reversed, i.e. the child is the more competent partner in the interaction. It is important to note that the robot, even though being the less competent partner in terms of learning content, still has to act as the “expert” in terms of structuring the situation, by being “clear in guiding the interaction” [15, p. 6].

The goal of our project is thus to contribute to insights on how children engage with a robot when their role is the one of the ‘expert’ within a routinized, and thus, familiar interaction format, namely book reading. However, before investigating whether and how this situation – when applied in child–robot interaction – can be used as a language learning scenario, the interactional requirements for a successful dialogue have to be studied. Our goal is to reveal whether four-year old children will engage with a robot in a word-learning task without the support of a caregiver, and to investigate the interactional behavior of the children. While in previous research summarized above, it was already demonstrated that cHRI is possible with preschoolers, recent studies [31] also reveal that the interaction needs to be supported by the caregivers and some children cannot cope with interactional breakdowns on their own. This finding calls for the necessity to further investigate interaction designs, which are manageable for children and give them the possibility to act on their own. More specifically, we aimed at: (1) observing how four-year old children draw on the interactional frame of book reading, a frame they are familiar with, when interacting with a robot in a teaching scenario, and (2) to investigate how the robot’s behavior has to be shaped to enable it to not only successfully participate in an interaction with a child but also to structure a learning setting within a book reading situation.

2. Research Plan

2.1. Choosing the material used in the teaching task

The design of our research plan was driven by the following reasoning: To reverse the roles in a word-learning scenario (i.e. the child is teaching the robot), we needed to find appropriate learning content that a preschooler can teach. The learning content should not be too simple because the robot – even though being the one being taught – has to structure the situation [15], i.e. has to introduce the game using complete sentences, and interact with the child using questions. Thus, for the word-learning scenario within the situation of joint picture-book reading, we assumed that teaching words for simple objects (nouns) or actions (verbs) to a robot who is able to give more complex instructions might not be plausible to the children, and thus we decided not to use an early-concept book [32]. Early-concept books are characterized by depicting one object per page, and to elicit mostly nouns (e.g. ball, cookie) or verbs (e.g. hit the ball, eat the cookie) [32]. Instead, we chose a

book about color names (“Zitronengelb und Feuerrot” [Lemon yellow and flame red], [33]) that is similar to a concept book. In addition, the book content seems manageable for and known to a four-year old child — a basis for the child to take the teaching role, e.g. it did not require the child to be able to read. The book we chose [33] depicts 50 colors, with one color and the color word printed on the left page, and a corresponding illustration on the right page (e.g. “sunflower yellow” on the left page, and a picture of sunflowers on the right page). A book with more complex pictures, in which each double page depicts an illustrated scene with many different characters and stories, provides many different possibilities for the child to talk about the pictures, thus making programming of the robot in terms of the learning content as well as meaningful interactional behavior more challenging and possibly more susceptible to interactional breakdowns.

2.2. Interaction design for the pilot study

The hardware platform used in this study is the humanoid robot NAO developed by Softbank Robotics. To program the robot’s interactional behavior, we used the Choregraphe Software also provided by Softbank Robotics. For this pilot study, we only used the speech recognition; apart from that, we did not use any other sensors such as vision during the interaction. For the speech recognition, a list of words that were likely to occur at a certain stage of the interaction, was preset for each stage. The robot’s exact verbal and nonverbal behavior as well as the length of the pauses in between were also preset. The lengths of the pauses were determined according to the observations made in a previous cHRI in our laboratory with a group of children playing an imitation game with the robot. The designed interaction comprises of the following steps:

1. *Introduction:* After standing up from a sitting position, the robot introduces itself by saying its name, and then asks the child for his/her name.

2. *Introduction of joint book reading scenario:* The robot introduces the book reading situation by telling that there is a book while pointing to it, and encouraging the child to have a look at it. After a short pause (which was fixed to 3,5 seconds), the robot asks if the book is about colors (followed by a pause lasting 1,5 seconds). We decided to use a more dialogical structure including questions to introduce the book, the situation and the task, rather than a whole, monological instructional sequence, to make situation structuring more natural and interactive, and thus to introduce the robot as a peer. As [15] have pointed out for cHRI, the first presentation of the robot is very important “on the way in which it is subsequently perceived and the ‘believability’ of the interactions.” [15, p. 5]. Thus, the robot tells the child that it does not know much color words yet, and by that introducing itself as a less competent partner. Finally, the robot invites the child to teach it some new color words and to read the book together with the child.

3. *Preparation of joint book reading:* Because joint book reading usually takes place in a comfortable position, the robot sits down while commenting on its behavior, and then invites the child to sit down next to it and to place the book in front of both of them.

4. *Teaching color words:* In this phase, the child teaches the robot the color words. However, the robot structures the situation [15] by asking the child to turn the page and to label the color depicted on the page. Because each page also shows an object, animal, or person in the particular color, speech recognition together with the “switch case”-feature is used so

that the robot can respond contingently and appropriately [11], [34] to the children’s verbal utterances given the requirement of the task to teach color words: If the child labels an object, animal, or person, it is asked to label the color again. The robot’s verbal utterances change slightly for every page in order to make the interactive behavior appear more natural. Once the color word is taught, the robot asks to turn to the next page. From the 50 colors in the book, we chose 10 of them in this pilot study. The book was manipulated with gluepads so that only those 10 pages could be opened.

5. *Robot labeling phase*: When the child reaches the final page, the robot introduces this phase by saying that it has learnt some new color words and wants to share this new knowledge with the child now. The robot was programmed here as knowing half of the color words, and as either being unsure (“Here, I am not sure. Let me guess? Is it purple?”) or not knowledgeable at all (“Oh, I can’t remember this color. Can you help me?”) of the names for the other half of the color words. These conditions are used to explore whether and how interaction is shaped by it and how the child will respond to different levels of knowledge. Following every labeling attempt, the robot asks the child to evaluate whether the color word was right or wrong, and proceeds only if the child gives some kind of feedback.

6. *Closing*: In this final phase, the robot thanks the child for reading together, hopes that they meet again, and says good-bye.

3. Pilot Study

For the pilot study, a 4;8-year-old boy interacted with the NAO robot. He was a little familiar with robots beforehand, i.e. he had already seen a NAO before and had watched a video showing this robot. The interaction between the child and the robot lasted around 8 minutes and was subdivided into the stages described in 2.2. The experimenter, a person the child knows well, was in the room with the child, the mother waited outside. Here, we report our first observations focussing especially on the breakdowns indicating difficulties in the flow of interaction:

First of all, with the child already present, we noticed that the situation also had to be framed spatially, i.e. the space in which the joint book reading was supposed to take place had to be defined by placing a cushion on the floor next to the robot (see Figure 1).



Figure 1: *The spatial arrangement for the joint book reading situation.*

Second, even though the child looked forward to playing with the robot beforehand, as soon as the interaction was about to start, the child seemed to be uncertain about what to expect,

and signaled that he prefers to observe an interaction between the experimenter and the robot from the opposite side. The experimenter assured that they could do it together and sat down next to him. After initially feeling uncomfortable when the robot first moved to stand up and to introduce itself (step 1), the child showed interest in the robot, and, encouraged by the experimenter, said his name after being addressed by the robot. Here, it is important to highlight that the very first moment of the interaction and the child’s knowledge about what to expect from the robot is crucial for child’s engagement.

In step 2, in which the robot introduced the joint book reading scenario, the child followed the robot’s initial instruction, picked up the book and looked at it. However, we noticed that the pauses between the single questions that the robot asked here were too short (pauses were fixed, see 2.2.): The child was still exploring the book, when the robot moved on to the next questions, and did not answer them. With respect to the material used in this study, it is important to give the child the possibility and the time to explore it on her or his own. At the same time, the robot needs to be able to structure the situation.

Timing was also an issue in the following step when the child was asked to sit down next to the robot on the floor (step 3), and again needed support and encouragement from the experimenter. Before the child was finished sitting down and placing the book in front of both of them, the robot had already moved on to step 4, and instructed the child to open the book and to label the color word. In cases like this, the robot’s interactional behavior in terms of timing needs improvement.

However, at this stage of the interaction, the child seemed to be willing to interact with the robot and teach new words to it. While looking at the first page (showing the color green), he labeled the animal depicted on the right page of the book (“a frog”), and then visually checked with the robot for its reaction. The visual checking was achieved by looking from the book at the robot. Because at this point, speech recognition did not seem to detect any word, the robot did not respond (2,7 seconds), and the experimenter asked the child to say it again and speak louder. Interestingly, the child was able to modify his input, following some parameters known from parental input, e.g. [35], [36]. That is, the child repeated the word louder and more emphasized, now without the determiner (i.e. he just said “frog”), and also used nonverbal communicative means: He moved closer to the robot’s “ear” and pointed at the color on the page.

Because the robot had introduced itself as willing to learn color words, it did not accept other labels such as animal names (see 2.2., step 4). Thus, when the child labeled the frog on the right page, the robot asked for the color label in turn, which the child provided. So, labeling the first page might have served as an initial negotiation about what exactly is being taught. At the following pages in the book, the child kept to a similar pattern when teaching the color words and interacting with the robot: He labeled the color by saying the single color word, and waited each time for the robot’s instruction before turning the page. During this teaching phase, there were three communication breakdowns, additionally to the one reported above. In one case, the robot’s speech recognition did not seem to detect any label, while in the other two cases it did not recognize that the child had already said a correct color word. In the former case, the child looked at the robot and waited almost 4 seconds for a reaction, then he successfully applied the strategy that had been successful before: He spoke louder and with greater emphasis,

followed by visual checking with the experimenter. In the two latter cases, the child seemed to think about another way of labeling the depicted color. In the first case, he also tried to apply the strategy successfully use before – speaking louder and repeating the word again – but due to some technical issues he could not resolve this breakdown, and thus the experimenter assisted. Interestingly, for solving the third communication breakdown, the child reformulated his utterance by embedding the color word within a phrase (“the blue fish”), a strategy that the experimenter had used in the preceding breakdown. In sum, we observed that the child kept a certain pattern when labeling the color words, and that he drew on strategies that had been used successfully before when the robot’s communicative behavior broke down.

Following this teaching phase, the robot presented itself as willing to share the newly acquired color words (step 5). Here, we observed that this change in the interactional role, even though communicated by the robot, was not obvious or explicit enough to the child, who remained in the routine of labeling the colors instead of letting the robot name the colors now. This might be a result of our study design: The robot was designed to know half of the color words, but to need help with the other half, thus asking the child to teach again. Consequently, different roles were requested – either the role of evaluating how well the robot had learnt, or the role of teaching the label again. In most cases, the child did not evaluate the correctness of the robot’s utterances without the help of the experimenter because it did not seem to be clear enough which interactional roles was expected. In sum, it seems to be important that the robot structures the interaction even more explicitly, by “telling the child what to do and when” [15, p. 6].

Interestingly, when telling about the interaction with the robot afterwards, the child remembered those words best that the robot was uncertain about and labeled wrong.

4. Discussion and Conclusions

With our pilot study, we introduced another interaction format – joint book reading – that is applicable in cHRI as it is a format that children are usually familiar with [18], [22]. Our first goal in this study was to observe how children draw on the interactional frame of book reading when interacting with a robot in a teaching scenario. The observations from our pilot study suggest that children are familiar with the pragmatic frame of book reading, can apply their knowledge to an interaction with a robot and can teach new words to it. With respect to the dialogical abilities, we observed that the child was able to modify his verbal and nonverbal input, following some parameters known from parental input within joint book reading [36]. However, when communication broke down due to technical issues such as the robot’s failing speech recognition, a 4-year-old child seems to need assistance from an adult / experimenter who mediated the interaction, e.g. instructed the child or even talked to the robot, to repair this communication. Communicative breakdowns might occur because preschool aged children are too young to know how to identify and repair communicative problems. However, child–robot interactions, in which roles are reversed are applied with children as young as two years of age [37], and, as [38] state, this approach “is particularly adapted for young children” [38, p. 54]. Also, if robots are intended as a tool for interventions with children at risk (e.g. for language delays), they have to be able to interact with young children, raising thus the value of early interventions. Consequently, interaction formats that are

manageable for younger children should be designed and investigated.

One could argue that communicative breakdowns could result from the type of interaction that we chose, because they might be too complex for preschoolaged children. However, we do not share this view, because from early on, language and development takes place in complex interactions and children benefit from interactions that provide them with a clear (yet complex) goal [23]. In this sense, the interaction format we used to embed the word-learning task – book reading – is highly structured in a predictable way, thus making its goal manageable for the children.

There are some other points concerning the robot’s interactive behavior that need to be further considered in the design of the interaction:

Overall, we noticed that the timing of the robot’s interactional behavior needs improvement, especially pauses that seemed to be too short in some cases: for example, in step 2, when the child needs time to explore the book before the robot introduces the joint book reading scenario. Also, preparing the book reading situation (step 3) needed more time than we had expected before. Thus, as it seems to be crucial that the interaction is clearly and explicitly structured by the robot, it has to be ensured that instructions are given only when a previous action is completed. This element is needed to introduce a clear organization of the behavioral sequences that are shared between the robot and the child. Because timing within the cHRI is probably something that is quite individual and dependent on various contextual factors, a more flexible way to adapt to the temporal sequencing of the interaction might improve this issue. So instead of using preset, fixed pauses between the different steps in our interaction design, one possibility is to use the robot’s touch sensors on its head or arms, i.e. the robot moves on only if the children express their readiness by touching the robot’s head or arms. However, it was observed that performance scores are rather low when children are instructed to touch a robot [39], i.e. they are reluctant and unsure about how to behave, particularly when they have not interacted with the robot much before [39]. For a more flexible way of the temporal sequencing of the interaction by using the robot’s tactile sensors, children should become more familiar with the robot and its way of moving and interacting, e.g. by playing warm-up games.

Another possibility to improve the timing would be to use the robot’s motion detection and visual information about the current spatial position and action taking place, as touch is not a common way of interaction. This way, an interaction with the robot could be more natural.

Another point concerns the guidance of the dialogue: In the here proposed cHRI, the robot guided the interaction, thus it had assigned the roles to the interactional partners. We observed that the child readily accommodated to the assigned role but had difficulties in recognizing its change, or switching between different roles based on the current requirements (i.e. evaluating of robot’s performance or teaching again). Clearly, more effort has to be made to design a clear role reverse that the child will intuitively accept.

Finally, for further studies, we need to implement a greater repertoire of verbal and nonverbal communicative behavior that is activated when communication breaks down, and that states the possible cause (such as speech input being not loud enough) as well as some instruction on how to overcome such breakdowns, e.g. asking the child to speak louder, putting its

hand to its ear, or moving its upper body closer to the child, thus reducing the necessity of adult assistance for a successful cHRI.

At this stage of the project, our primary goal was not to enhance learning in children, but to test whether the interaction format of book reading that children are familiar with is applicable in cHRI. Thus, we chose words that the child was likely to know. However, in future studies, our goal is to investigate how this format can be used to contribute to children's language development. One possibility is that children are taught morphologically more complex words, such as compounds (e.g. "snow-white", "pitch-black"), during ostensive labeling provided by an adult teacher. Subsequently, the robot could serve as a tool to support learning: By teaching those newly acquired words to the robot (learning by teaching approach), the children consolidate their word knowledge, and retrieve the word form as well as its semantic information [40]. The advantage of presenting the new words within a book reading format is that this frame is repeatable [21] and the words can occur frequently. Further, it can serve as a test whether the children transfer their knowledge, i.e. whether they use compound words as labels for unknown color words.

In our pilot study, we also observed that the child was more responsive to a robot that was not knowledgeable, and had greater memories about those moments in interaction in which the robot displayed uncertainty. This bears a great potential for specific learning: a non-knowledgeable robot can systematically apply errors and thus, deepen the process of learning.

5. References

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