The Interplay of Robot Language Level with Children's Language Learning during Storytelling

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ABSTRACT
Children's oral language skills in preschool can predict their success in reading, writing, and academics in later schooling. Helping children improve their language skills early on could lead to more children succeeding later. As such, we examined the potential of a sociable robotic learning/teaching companion to support children's early language development. In a microgenetic study, 17 children played a storytelling game with the robot eight times over a two-month period. We evaluated whether a robot that "leveled" its stories to match the child's current abilities would lead to greater learning and language improvements than a robot that was not matched. All children learned new words, created stories, and enjoyed playing. Children who played with a matched robot used more words, and more diverse words, in their stories than unmatched children. Understanding the interplay between the robot's and the children's language will inform future work on robot companions that support children's education through play.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces; I.2.9 [Artificial Intelligence]: Robotics-*Commercial robots and applications*; J.4 [Computer Applications]: Social & Behavioral Sciences-*Psychology*; K.3.1 [Computers and Education]: Computer Uses in Education

General Terms
Experimentation, Human Factors

Keywords
Education; language; learning; long-term interaction; play; social assistive robotics; sociable robots; storytelling

1. INTRODUCTION
An important factor in children's academic success is their early language ability. Children who grow up with an impoverished exposure to English – such as fewer total words heard, fewer novel words heard, and a lack of rich vocabulary-building curricula or cognitively challenging tasks in preschools – show language deficits that may negatively affect the child's entire academic career [4, 10]. These results reveal a great need for interventions that can support children in developing critical language skills. Furthermore, because language lives in a social, interactive, and dialogic context, ideal interventions would not only teach vocabulary, but would also engage children as active participants in meaningful dialogues [3].

Social robots could potentially have great impact in this area. They merge the benefits of using technology – such as accessibility, customization and easy addition of new content, and student-paced, adaptive software – with the benefits of embodied, social agents – such as sharing physical spaces with us, communicating in natural ways, and leveraging social presence and social cues [1]. Several successful robotic learning companions have been developed for early language education in recent years, with most teaching vocabulary to preschool children through a variety of games and activities [e.g., 5, 8, 11].

To this end, we developed a robotic learning/teaching companion that could support children's early language development by playing a storytelling game. Storytelling can support emergent literacy [2] and function as a platform for learning, practicing, and constructing one's own language in a collaborative, social context. We investigated three questions: First, to what extent could a robot facilitate children's oral language development? Second, following the theory that a learner will learn best when in the zone of proximal development [12], could matching the "level" or complexity of the language used by the robot to the child's general language ability (so that the robot presents an appropriate challenge) lead to improved learning outcomes? Third, how might children construe a robotic companion over time, and what kind of relationships might they build?

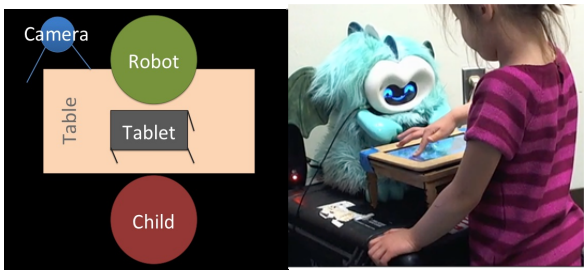

Figure 1: In the study, the robot sat on the table across from the child. The shared storytelling game surface on the tablet is set into a small wooden table.

2. METHODS
Participants were 17 typically-developing children ages 4-6 (10 female; 7 male) from two Boston-area preschools (9 from the first and 8 from the second). Each child played with a DragonBot robot (Wizard-of-Oz controlled) eight times over two months (Figure 1). During each session, the robot and child played a storytelling game inspired by [10] in which they took turns telling stories about characters shown on a tablet screen. The tablet was inset in a small play table and acted as the shared context for the game.

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The robot introduced new words in its stories and modeled more complex ways of telling stories (e.g., using more complex sentence structures – described further in [7]). At the beginning and end of each session, the robot chatted with the child about how the day was going, shared little stories about its own 'life', and reflected on the time spent together. We interviewed children about their perception of the robot and game after sessions four and eight (described further in [6]). Audio and video of all sessions was recorded.

Children were given an initial language assessment. We performed a median split to sort the children into 'higher' and 'lower' language ability groups. For the first four sessions, the robot told easy stories to all children, as a baseline. For the final four sessions, the robot's story level (easy or hard stories) was *matched* or *unmatched* to the child's language ability ('lower' or 'higher' ability). However, we have not yet finished data collection for one condition (lower ability, harder stories), so here, we report initial results for just the higher ability matched (4 children) and unmatched children (4 children).

3. RESULTS

We found that across all higher ability children, knowledge of target vocabulary words introduced by the robot during its stories increased by a mean of 3.8 words (SD = 2.9), $t(7) = 3.72$, p=.008. These children told a total of 78 stories with a mean length of 100.8 words (SD = 54.0). Their stories used the same number of total words and different words on average during sessions 1-4 (when they all heard easier stories). During sessions 5-8, stories told by matched children were longer (M = 169.0 words, SD = 80.0) than those of unmatched children (M = 84.7, SD = 91.7), $t(33) = 2.87$, $p = .007$. Stories told by matched children (M = 86.2, SD = 25.0) contained more different words than unmatched children's stories (M = 46.4, SD = 43.6), $t(33) = 3.23$, $p = .003$. No differences by condition were seen in children's engagement with the robot – during the final interview, most children said they liked the game a lot (87.5%), wanted to play again (100%), that the robot was their friend (87.5%), and that the robot's stories were interesting (87.5%) and understandable (100%).

4. DISCUSSION

In this work, we investigated the potential of a robot companion to support children's oral language development through play, and children's construal of and relationships with a robot during a long-term interaction. We addressed the social, interactive nature of language learning through a storytelling game, mediated by a tablet, that the child and robot played together. The initial results suggest that children can learn new words from the robot through the robot's stories. Playing with a matched robot may lead children to maintain the amount and diversity of words used in their stories, while playing with a robot of 'lower' ability than the child may lead children to in fact talk less and more simply, as if to a younger peer. Because data collection is still in progress, we do not know if matching leads to the most improvements; we may find that hearing harder stories is best, regardless of initial ability.

In addition, a child-robot interaction can add rich variation to how children learn. This work demonstrates that a robot can maintain engagement across many sessions with a child, while leading an educational play activity. This work also gives insight into the relationships children develop with robots over time and factors that influence how children interact with robots. Understanding how robots influence children's language, and in what ways robots can support language development will inform the design of future learning technologies.

Our future work takes two directions. First, we are continuing data collection, filling out the full 2x2 study. We are coding the videos of interactions to understand (a) children's non-verbal behavior with the robot, and (b) the timing of the tele-operator's control of the robot's non-verbal behaviors, so we can develop autonomous non-verbal behaviors for the robot. We are also working toward automatically transcribing and assessing children's stories, so the robot can respond autonomously in real-time.

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