Effects of a Listener Robot with Children in Storytelling

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ABSTRACT

This paper investigates the effects of a listener robot that joins a storytelling situation for children as a side-participant. For this purpose, we develop a storytelling-robot system that consists of both reader and listener robots. Our semi-autonomous system involves a human operator who makes correct responses and provides easily understandable answers to the children's questions during storytelling. We develop a gaze model for the natural and autonomous gaze behaviors of a reader robot by considering multiple listeners and a storytelling object (a display that shows images). We conducted an experiment with 16 children to investigate whether they preferred storytelling with/without the listener robot and the changes of speech activities during the storytelling. Children preferred storytelling with the listener robot to storytelling without it. Their speech activities decreased when the listener robot was involved in the storytelling.

Author keywords

Storytelling; human-robot interaction; two robots;

ACM Classification Keywords

H.5.2. User Interfaces: Interaction styles;

INTRODUCTION

Storytelling is a common human activity in childcare situations, it plays important roles in the language development of children and improves their language complexity [1, 2]. Based on its obvious importance, human-agent and human-robot interaction researchers have focused on the development of storytelling systems for children [3-9]. For instance, researchers explored the potential of storytelling systems for supporting children's language development [7, 8]. Using two robots enables different storytelling roles to be assigned, and this strategy might engage children more deeply and intently during storytelling [10].

We are also interested in the possibilities of using two robots for storytelling. Past research used two robots for storytelling, e.g., two readers by role-playing during storytelling [10] or two listeners for children's storytelling [11]. However, our perspective is different; we are investigating the effects of a listener robot that behaves like a *side-participant*, which is a *ratified participant* during conversations [12, 13]. Several research works reported that using two robots to show their conversations (speaker and listener robots) to people benefits information providing tasks [14] [15]. Similar effects might occur in storytelling with children.

In this study, we investigate the effects of a listener robot in a storytelling context by developing a semi-autonomous storytelling-robot system (Fig. 1). We deploy a semi-autonomous approach to accurately respond to such random behaviors of children as asking questions during storytelling to avoid speech recognition difficulties with children [16], by involving a human operator. Also, we developed a gaze controller model for the reader robot during storytelling to naturally and autonomously control its gaze behaviors. During storytelling, the listener robot actively behaves as a side-participant: asking the reader robot questions instead of the children, nodding during storytelling, etc.

Fig. 1 **Storytelling with two robots**

In this study, we address the following research question:

-Will children prefer a storytelling situation with both reader and listener robots?

-Will a storytelling situation with both reader and listener robots encourage or suppress children's speech activities?

RELATED WORK

Based on the progress of information technologies, using multi-media tools in storytelling has become increasingly popular. In fact, virtual agents and physical robots are often used as readers. With them, several researchers have developed autonomous storytelling systems for children. For example, Fourati et al. developed a virtual agent that displays facial expressions of appraisals related to story events and experimentally investigated its capabilities with children [9]. Bernardini et al. developed intelligent virtual agents for fostering social communication in autistic children through storytelling [17]. These works showed how virtual agents can be used as storytellers for children and their effectiveness.

Robots are also used as storytelling agents in education contexts [18]. For instance, Fridin developed a robot that tells two prerecorded stories to small groups of children and showed that it improved their cognitive and motor performances [6]. Kory et al. developed a storytelling system using a robot with preschool children to support their language development [7]. Storytelling-robot systems are used not only for storytelling but also for understanding children's behaviors. For example, Leite et al. compared how children's behaviors changed during storytelling with individual and group interactions through role-play-based storytelling with multiple robots [10]. Another interesting storytelling trial with robots investigated the effects of an attentive listening robot on storytelling with children [11]. These research works also scrutinized the possibilities of using robots in storytelling contexts.

Similar to these research works, we developed a storytelling system using tow robots for children; however, our main aim is different from this past research work. In this study, we focused on the effects of a listener robot during storytelling toward children. Past research works showed the effectiveness of using two robots to show conversations to people [14, 19], even if their tasks were different from storytelling for children. Even though we believe that using two robots to create third-party conversations in storytelling contexts will more deeply attract children and modify their activities, no such effects have been unveiled yet.

SYSTEM OVERVIEW

Figure 2 shows an overview of our developed system that consists of the following components: human-tracking system, gaze model, reader robot, listener robot, and a human operator who controls the speech recognition and behavior selector. The reader robot uses a display to show each page of the picture book during the storytelling. The details of each component are described as follows.

Human-tracking System

We used one depth sensor (Kinect V2) in the environment to estimate the positions of the children. The range for recognizing a person is from 0.5 to 4.5 m, the field's horizontal angle is 70°, and the field's perpendicular angle is 60°. This system sends the estimated head positions of the children using Kinect V2 libraries to other components by a network connection.

Gaze Model

In this study the reader robot must control its gaze by considering the children, the listener robot, and the display for natural gaze behaviors because we used a display that shows images during storytelling. Since several gaze models have already been proposed in multi-party conversations [20] [21] [22], we extended the existing a conversational gaze models for humanlike robots [20] during storytelling with three-party conversations to deal with similar contexts. Moreover, we addressed the presence of an additional gaze target (a display) to apply this model to our system.

In our model, we changed the gazing target ratios at the beginning of each sentence because a previous gaze model changed the gazing target ratios during storytelling [20]. When there is a listener robot in the model, the gazing targets are the display, the children, the listener robot, and the environment. Following past research work, we set our reader robot to look at the display with 0.70 probability at the beginning of each sentence and at the listeners with 0.73 probability at the non-beginning of each sentence. Based on the previously defined gaze ratio probability [20], we set the values at the beginning of the targets to 70.0%, 3.9%, 3.3%, and 22.8% and the values at the not-beginning of the targets to 10.3%, 39.5%, 33.5%, and 16.7%. Thus, at the beginning of each sentence, the reader robot mainly looks at the display; at the not-beginning of each sentence, the reader robot mainly looks at the children or the listener robot. When the gaze target is the environment, the gaze angle was randomly decided from the front of the robot to the display. Without a listener robot, the gaze target ratio is added to the children's ratios. We decided that the gaze target changes every three seconds.

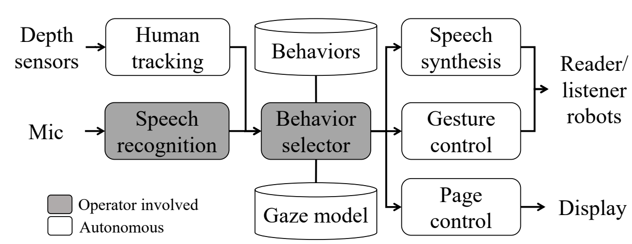

Fig. 2 System overview

Fig 3 Sota

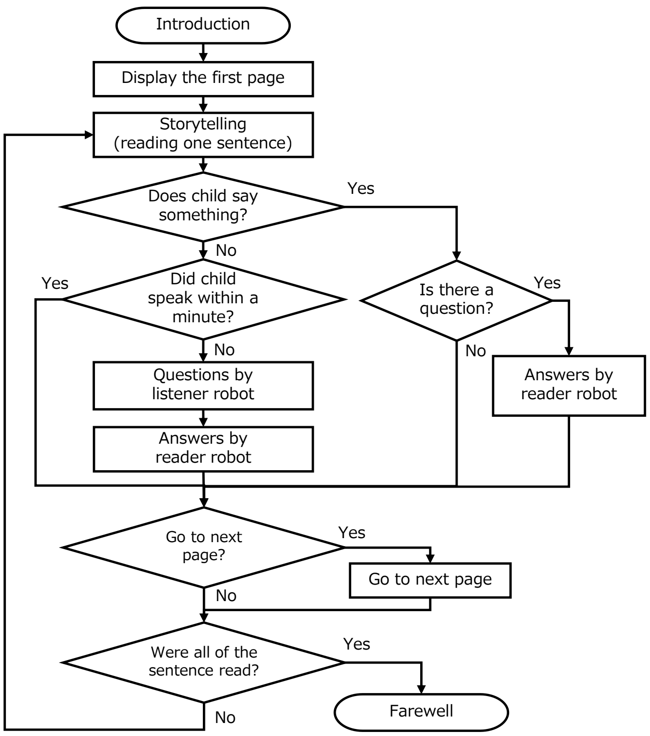

Fig. 4 Dialog flow

Robot

Figure 3 shows Sota, an interactive humanoid robot characterized by its humanlike physical expressions. We used two Sota robots: a reader and a listener. Sota has eight DOFs: three in its head, one for the shoulders, elbows, and base. It is 28 cm tall and is equipped with a voice synthesis. The LED on its mouth blinks depending on the sound level to indicate speaking. The robot gazes are autonomously controlled by the proposed gaze model described above. The robots' shoulders slowly move as an idling behavior.

Operator

For this study, an operator assumed the speech recognition and behavior selector functions using a tele-operation system (Wizard of Oz [23]) and followed pre-determined rules. Our system enables the operator to select the speech recognition results based on pre-determined candidates, and then the robots autonomously decide their actions using the speech recognition results.

If no appropriate answers exist towards children's questions, the operator uses Sota's text-to-speech function to answer them quickly. Also, the operator decides the timing of the utterances during storytelling, because we can't predict when children will ask the robots questions.

Details of Implemented Behaviors

An overview of the dialogue flow is summarized in Fig. 4. After the storytelling begins, the reader robot looks at the child and the listener robot and starts to read. Both robots semi-autonomously interact with the children, except for the speech recognition and behavior selections.

To implement our storytelling behaviors, we used two picture books: *Etwas von den Wurzelkindern* by Sibylle von Olfers (Nekko umare no kobito tachi in Japanese) and *Zucchini of Zuzu* by Leo Rivas (Zuzu no Zukki-ni in Japanese). Average reading times by our system are 5.5 and 3.5 minutes, respectively. We chose these books to avoid already known situations in our experiment, because both are written for young children, and neither are very common in our country yet.

Introduction

The reader and listener robots greet each child by name and introduce themselves through conversations. The children's names were registered before the experiment. For the children's acclimatization, both robots made small talk about the weather, for example. After introducing themselves, the robots start to tell the story.

Storytelling

The reader robot slowly reads a sentence of the picture book aloud, and then the listener robot nods once after each sentence. The reader robot controls the image on the display based on the storytelling's progress. During the storytelling the robot reader gaze behavior is controlled by the proposed gaze model.

Asking/answering questions between the robots

If the child fails to ask the reader robot a question within a minute, the listener robot asks a question itself, which the reader robot simply answers. Both the question and answering behaviors are pre-defined, and their timings are controlled by the operator. We prepared 38 asking behaviors and 29 answering behaviors based on the contents of the two books. For example, the listener robot might ask "what is a forget-me-not?" and the reader robot answers: "a plant with a blue flower." In some cases, since one answer behavior was used for different asking behaviors, the numbers of asking and answering behaviors are different.

Answering children’s questions

If the children asked the reader robot a question, it answers with prepared explanation behaviors based on speech recognition results from the operator. For this purpose, we prepared ten explanation behaviors. For example, if a child asks, “what is a zucchini?” the robot answers: “it's a cucumber-like vegetable.”

Requesting that a child return

If the child leaves before the storytelling session is finished, the reader robot asks him/her to return by calling by his/her name.

Farewell

After finishing the storytelling for each book, the reader robot thanks the child for listening and announces that the story hour is finished.

EXPERIMENT

Hypothesis and prediction: preferences

We predict that the presence of a listener robot will provide positive storytelling effects for children. For example, listening to conversations between robots enables the interacting partners to understand the content more easily [24]. Another research reported that people are more attracted to a dialogue between two robots than just a monologue from one robot [14]. These research works mainly reported on the effects of two robots toward adult participants, but we believe that such effects might also occur in child participants. Based on these considerations, we made the following prediction:

Prediction 1: Children will prefer a storytelling situation with both reader and listener robots compared to storytelling only with a reader robot.

Hypothesis and prediction: speech activities

Moreover, we assume that the listener robot’s presence will change the children’s speech activities during storytelling. However, since the phenomena related to the number of robots and their roles remain basically unexplored and accurately estimating young children’s behaviors is difficult, we made two contradictory hypotheses about their effects based on different theories and considerations.

Hypothesis about stimulating children’s speech activities

We assume that the presence of a listener robot during storytelling will stimulate the children’s speech activities and prompt them to ask more questions, because showing conversations between robots enables interacting people to understand their contents more easily [24]. Moreover, asking behaviors by the listener robot might fuel the children’s curiosity about the story’s contents. In fact, a past work at an elementary school reported that when a child asked a robot questions, other they were stimulated to ask additional questions themselves [25]. Based on these considerations, we made the following prediction:

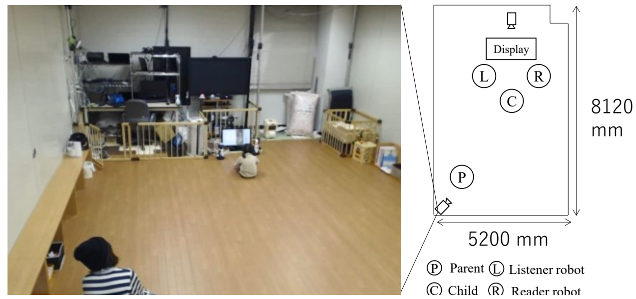

Fig. 5 Experimental environment

Prediction 2-a: The presence of the listener robot will encourage the speech activities of children, i.e., more statements and/or questions.

Hypothesis about satisfying children’s speech activities

We assume that observing conversations between reader and listener robots will satisfy children’s speech activities, and they will not ask the reader robot questions because the listener robot had already asked them. The presence of the listener robot might also change the role of the children from addressees to side-participants; if the children feel that the reader robot is mainly talking to the listener robot, they might behave less actively during the storytelling and focus more on the robots’ conversations. Based on these considerations, we made the following prediction:

Prediction 2-b: The presence of the listener robot will suppress children’s speech activities, i.e., fewer statements and/or questions.

Participants

Sixteen children (eight girls and eight boys from three to five years old, average age 4.3, S.D 0.86) and their parents (15 mothers and 1 father) participated in the experiment.

Environment

Figure 5 shows the experiment environment. The room is approximately 40 m^2. Toys, books, and chairs are available for the participants to represent a realistic playroom environment; already this environment was used for experiments in child-robot interaction research fields [26]. We placed reader and listener robots in front of the display and a Kinect V2 behind it. The child sat on the floor to look at the displayed picture book.

Condition

The study had a within-participants design with the following two conditions:

One robot: In this condition, we only used the reader robot. Without the listener robot, we didn’t use the asking/answering questions between the robots behaviors. The gaze model did not consider the listener robot to determine the reader robot’s gaze behaviors.

Two robots: In this condition, we used both the reader and listener robots. All of the behaviors in the “Details of implemented behaviors” section were used during the experiment. The gaze model considered the listener robot to decide the reader robot’s gaze behaviors.

Measurement

In this experiment, we measured one subjective item about the preferences by directly asking to children after the experiment which conditions they preferred. We also measured the number of children’s utterances during the storytelling to objectively investigate their speech activities toward it.

As supplemental measurements, their parents filled out a questionnaire that consisted of three subjective items: the naturalness of the reader robot gaze, their perceptions of their child’s enjoyment, and their preferred condition (one or two robots). The former two questionnaire items were single scale, evaluated on a 1-to-7 point scale (7 is most positive), and the last was a binary choice between conditions.

Procedure

Before the first session, the adult participants were given a brief description of our experiment’s purpose and procedure. The first ten minutes were used to acclimatize the children to the environment and the robots; during this period, the reader and listener robots greeted each other and talked. Before the storytelling began, the child participant sat in front of the display, and the adult participant moved away from her/his child.

Since it had a within-participant design, each child sat through two sessions of different conditions. The order of the conditions (one or two) and the picture books were counterbalanced. After each session, the adult participants filled out a questionnaire. After the experiment, the adult and child participants separately answered questions about their preferences to prevent bias.

The experimental protocol was approved by our institutional review board (reference number 17-501-5)

RESULTS

General Trends

In both conditions, in the typical interaction pattern, the children intently listened to the storytelling from the reader robot (Fig. 6). Each child mainly changed their gaze targets due to the timing of the changing situations of storytelling. For example, when the reader robot started to talk, a child generally looked at it and then at the display. When the listener robot asked a question, the child looked at it and then at the reader robot and quietly listened to the story in both conditions. Sometimes the child focused on a specific part in a book’s picture when the listener robot asked a question (Fig. 7), e.g., approaching the display to examine the ladybug after the listener robot asked about it.

We observed some atypical behaviors during the interactions. For example, one girl stroked the heads of the robots or hugged them during the storytelling (Fig. 8). These scenes suggest that the children are interested in both the storytelling and/or the robots. On the other hand, children moved around during few seconds four times in both conditions, seemingly distracted by toys or approached their parents. After they started to move around, the system detected their positions and then the reader robot asked them to come back and listen to the story. They immediately returned to the front of the display and listened until it was over.

Fig. 6 Child listened storytelling in the single condition

Fig. 7 Child pointing at a specific part of the display

Fig. 8 Girl hugging the robot during storytelling

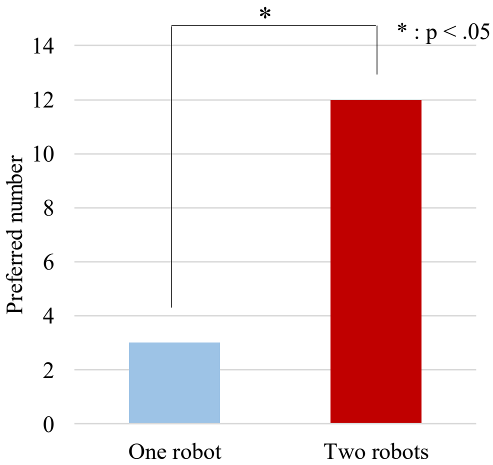

Fig. 9 Number of robots preferred by children

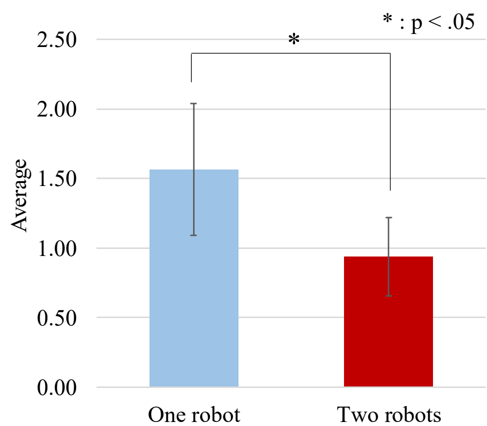

Fig. 10 Average number of children's utterances

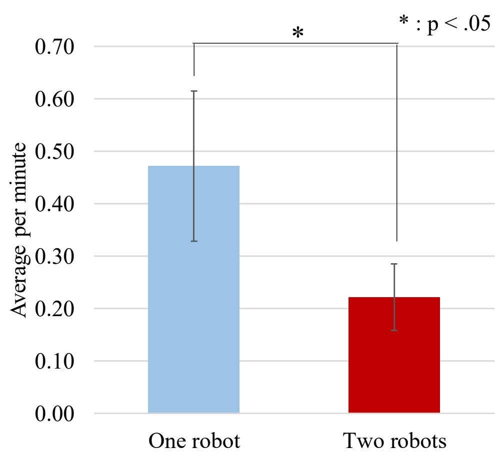

Fig. 11 Average number per minute of children's utterances

	Statements	Questions
One robot	29	1
Two robots	13	3

Table 1 Categorization of children's utterances

	Gaze naturalness	Children's enjoyment	Preferred number of robots
One robot	4.94 (0.36)	4.31 (0.37)	8
Two robots	5.25 (0.27)	4.69 (0.43)	7

Table 2 Questionnaire results from adult participants

Verification of Prediction 1

Fig. 9 shows whether the children preferred one or two robots in the conditions. Since one child could not decide which condition she preferred, we eliminated that child. We conducted a two-tailed binomial test and it indicated that the proportion of preferred number for two-robots condition of 0.80 was higher than expected 0.50, p=.035 (2-tailed). Therefore, prediction 1 was supported.

Verification of Prediction 2

Fig. 10 and 11 show the average number of children's utterances and their average number per minute. To verify the activities of each condition, we conducted a paired t-test for them. For the average number of children utterances, we found a significant difference among the conditions ($t(15)$ = 2.179, p = .046, r = .49). For the average number of children's utterances per minute, we also found a significant difference among the conditions ($t(15)$ = 2.420, p = .029, r = .53). These results indicate that the children spoke less in the two-robot condition than in the one-robot condition; prediction 2-b was supported.

Analysis of Children's Utterances

We analyzed the children's utterances during the storytelling by separating them into two categories: statements and questions. Two independent coders who did not know our research hypothesis classified them (Table 1). Their judgment matched reasonably well and yielded a Cohen's kappa coefficient of 0.726. We conducted a chi-squared test, but there was no significant differences between them (p=.011). No correlation between the number of utterances and ages was observed in either condition.

As shown in Table 1, their utterances are mainly statements in both conditions, e.g., a child said "a snail" when she saw a picture of one during the storytelling. Some children asked such questions as "what's a zucchini?," and then the operator made appropriate responses with the prepared answering behaviors.

Additional Analysis from Adult Participants

Table 2 shows the questionnaire results from the adults. First, to investigate whether our gaze model worked well in both conditions, we conducted a paired t-test for feelings of naturalness about the reader robot's gaze. The results showed no significant differences between the conditions ($t(15)$ = 1.232, p = .237, r = .30). Since the average values of this item at least exceeded the middle (four) in both conditions, our developed gaze model seems to adequately work regardless of the number of robots.

Next, to investigate how much the adults thought their children enjoyed the storytelling, we conducted a paired t-test on their subjective feelings of the children's enjoyment. The results showed no significant differences between the conditions ($t(15) = 1.065$, $p = .304$, $r = .27$). A two-tailed binomial test on the preferred condition metrics also showed no significant differences (p=1.00) between conditions; one adult could not decide which condition she preferred. Thus, the preferences and the perceived children's enjoyment did not completely match.

DISCUSSIONS

Design Implications

This study provides several implications. First, children significantly preferred the two-robot condition over the one-robot condition. This result shows a similar phenomenon with adult participants that was reported in past research [14]. Based on this study and past study, using two robots would be useful to attract people to robot contents regardless of the ages of the participants. Of course, in reality using two robots increases installation costs. Our experimental results provide evidence that can be used in discussions about cost-benefit balances (a use of multiple robots would be preferred by children but will be expensive) with two robots for various services.

The next implication is the significant decrease in the children's speech activities during storytelling with two robots. We believe that this phenomenon has both positives and negative effects on storytelling. For the positive aspect, decreasing the speech activities of children might focus more of the children's interest on the storytelling itself, especially since the children in our study preferred the two-robot condition. We only investigated the effects of robots with audiences comprised of a single child. But if this effect were to appear in a situation where many children are participating in storytelling, it might quietly attract them and reduce noisy situations. On the other hand, decreasing their speech activities (including questions) might suppress active participation in the storytelling. In other words, children might just passively participate in the storytelling by observing the robot conversations. Appropriate situations for using either a single or two robots for storytelling might depend on particular purposes; e.g., if a user wants a child to actively participate in the storytelling, a single robot might be appropriate. If a user wants a child to quietly listen or the participation of many children, two robots might be more appropriate.

Toward Autonomous Storytelling

In this study, we developed a semi-autonomous storytelling-robot system to investigate the effects of a listener robot. One technical future work is to increase the autonomy of our storytelling system.

In this study, the operator controlled the speech recognition functions. Because the success rate of current speech recognition systems is only 21.3% [27] in real environments, children's speech recognition remains difficult [16]. Another problem is that children often ask unpredictable or inexplicable questions. Since ignoring them or offering dismissive answers would probably discourage their interest in storytelling, we used a human operator as a speech recognizer. Past research also reported that one operator might be able to control four or more mobile social robots in a shopping mall environment [28, 29]. Therefore, we are optimistic that our semi-autonomous approach is appropriate based on the limitations of current technology and cost-efficiency issues.

Yet current technologies continue to have difficulty accurately recognizing speech, as shown by iPhone's Siri and Google speech recognition. The future growth of data for training such systems will improve the performance of speech recognition for children. We need to gather more speech data from children using robots; using tele-operated robots is important for gathering additional data and developing more autonomous systems.

Limitations

Since our experiment was conducted with our robot system and its specific settings e.g., only using two robots, knowledge generality is limited. We cannot confirm whether our finding about using two robots for storytelling can be applied to other kinds of storytelling robots or different contents. Moreover, since clearly measuring the subjective impressions of such young children is difficult, more analysis with objective measurements is critical.

In our study, we did not compare a situation where both robots act as readers, as in past research. Moreover, since we used a listener robot that asks the reader robot questions, the information amount was different between conditions. These facts should be addressed in discussion of our results.

In addition, we only compared the effects of different roles by using robots, not focusing on people and/or virtual agents. One interesting future work is to investigate the effects of using different existence.

However, we believe that our setting is adequate to offer knowledge for readers who are interested in child-robot interaction and storytelling with two robots.

CONCLUSION

We developed a semi-autonomous storytelling-robot system that consists of a reader robot and a listener robot. For natural storytelling behaviors, we developed a gaze model to control the reader robot based on multi-party conversation settings, including an object. To investigate the effects of the listener robot on the preferences and the activities of children, we conducted a within-participant experiment where our robot system reads stories to children. The experimental results showed that children preferred storytelling with the listener robot more than without it. Moreover, interestingly, their speech activities decreased during storytelling with the listener robot. These results would provide positive evidences to a use of multiple robots for child-robot interaction.

Currently we are working about increasing autonomy of the proposed system to deal with storytelling for multiple children. We will investigate the effectiveness of the proposed system towards more complex situations, and consider comparisons between the multiple agents/people for storytelling.

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