Investigation on the Roles of Human and Robot in Collaborative Storytelling

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***Abstract*—The tradition of storytelling is a distinctive human experience. There have been increasing evidences from social sciences that storytelling facilitates skill development in children. In this paper, we explore the use of humanoid robots to augment traditional storytelling, an area still understudied, to investigate the effectiveness of human-robot collaboration (HRC) in storytelling. In this preliminary experiment, a humanoid robot, Aldebaran's Nao, was programmed to recite a mystery story to 60 students aged 14 to 15, while engaging them through gestures, simulated eye contacts and varied voices. Nao delivered the performance as either an independent storyteller, or as a collaborator with a human storyteller. We assessed the effectiveness of HRC by comparing the participants' preference over the two settings. We found that 1) most participants believe that HRC is effective and prefer HRC over the robot-only performance; and 2) the complementarily effective roles of human and robot storytellers in interacting with the participants provide a glimpse of evidence on the preference towards HRC. These results, provide a first step towards effective use of robots for collaborative storytelling in day-to-day situations, which is well placed to guide the design of robots for education and entertainment purposes, e.g. for improving family bonding between parents and children while allowing parents to more effectively tell stories.**

I. Introduction

The oral tradition of storytelling dates back to the beginning of human history. It has always been a method of communication to pass information, knowledge and traditions across generations, especially before the invention of written languages. In addition, storytelling has been increasingly studied in recent decades and recognized as an important technique for skill development in children. For instance, many studies have documented the educational values of storytelling, including improved listening and reading comprehension [1], as well as greater vocabulary and language fluency [2].

Given the values of storytelling and the increasingly prevalent use of personal robots, it is natural to explore the use of humanoid robots in storytelling. There have been several studies on robot storytelling arguing for its competitive edge against human storytelling, which focused on the impacts of robot gestures [3] and gaze [4] on storytelling. The latter study also suggests that applications such as robot storytelling have the greatest potential for near-term success, because scripted performance reduces the requirement for sensing and responding to environment stimuli.

Previous studies have focused on robot-only (RO) storytelling. However, a natural alternative is to use robots as collaborators alongside human storytellers especially given the importance of family bonding activities in shaping the personality and character of children. We call this alternative human-robot collaboration (HRC) in storytelling. In this paper. we explore the use of HRC and compare it to RO storytelling. We assess the participants' preferences over the two scenarios and identify the participants' justifications for their preferences. The experiment addresses the following research questions: 1) *how could robots best augment the traditional storytelling experiences?* and 2) *what factors contribute to the preferences between HRC and RO storytelling?*

To answer these questions, we built on our previous work [5] and conducted a more extensive set of experiments with secondary school students (N=60) aged 14 to 15, A humanoid robot, Aldebaran's Nao, was programmed to recite a mystery story by the title of "Lamb to the Slaughter". To maximize Nao's performance in shaping desired outcomes such as information recall and engagement, we built upon existing literature from human-robot interaction [4], [6], [7], [8] and incorporated into Nao various gestures and simulated eye contacts while generating its speech an on-board text-to-speech (TTS) system. We included different voice profiles for different characters in the story. Experiments were conducted for the story told in HRC and RO settings, after which a survey was given to the subjects to understand their preference between the two settings. The participants were asked to justify their preferences and to also compare the performance of the human and robot storyteller within HRC setting.

Our preliminary results show that 1) most participants believe that HRC is effective and prefer HRC over the robot-only performance; and 2) the complementarily effective roles of human and robot storytellers in interacting with the participants provide a glimpse of evidence on the preference towards HRC. The contribution of our work is two-fold: 1) we propose a novel collaborative method for robots to augment the traditional storytelling and show it is effective; 2) we highlight the relative strengths of robot & human storytellers to guide the design of future educational & entertainment robots.

The paper is structured as follows: we discuss background and related work in Section II, followed by detailed description of experimental design in Section IV. We present our hypothesis in Section III, followed by the results in Section V. The discussion of the results is in Section VI and conclusion in

VII.

II. Background

In motivating our work and constructing appropriate experimental design, we build upon existing literature from several domains, including human robot interaction, social sciences, and speech synthesis. The following sections provide an overview of the related works.

A. Benefits of Storytelling

Considerable research in education and psychology has examined the effects of storytelling on skill development of children. Storytelling has been shown to improve listening and comprehension [1], greater language fluency, increased vocabulary [2], and general knowledge about the world [9]. As an interactive process, it also enhances children's poise and ability to interact [10]. Further, storytelling, as an communication form, facilitates the understanding of social norms, morality and other experiences, both within and across cultures [2].

B. Features to Shape Key Outcomes in Communication

A great deal of studies in social sciences have focused on how gaze and gestures influence communication outcomes such as information recall, rapport and engagement. We review related works in gaze and gestures, which have been also studied in human-robot interactions and are applicable to the implementation on the Nao robot used in our experiment.

1) Gaze: Gaze augments speech in communicating verbal utterances and emphasis [11]. Based on the content and structure of the speech, people direct their gaze accordingly [12]. Gaze is critical in communicating information about attitude and affect between speaker and listener. For instance, people who look at others more are judged more favorably for friendliness, competency and credibility. In addition to its social functions, gaze improves task performance. Studies have shown that gaze improves information recall [13] and performance at a learning task [14].

2) Gestures: Gestures convey important information about speech by emphasizing or augmenting spoken content [15], [16]. These impacts are observed in different cultures and regions [16]. In this paper, we adopt the terminology proposed by *Mcneill* to classify gestures into the following four categories: *deictics*, *beats*, *iconics*, and *metaphorical* [16]. We mainly utilize the deictic, iconic and metaphorical gestures in our storytelling robot. Moreover, it is found that gestures keep students motivated and engaged [17].

C. Key Features for Robot Storyteller & Related Applications

There is limited research on robot storytelling specifically. *Huang et al.* investigated, by regression analysis, how different types of robot gestures influence communication outcomes such as task performance and perception about robots in narration settings [3]. For instance, they found that robot diectic gestures consistently predict users' information recall. In another study, *Mutlu et al.* propose a gaze model by generalizing the performance of a professional storyteller and demonstrated that the model improves information recall[4].

In related applications from human-computer interaction (HCI) and human-robot interaction (HRI), gaze models have been proposed and studied for both virtual agents and physical robots. *Thorisson* implemented a computer agent which used gaze to express attentional cues [18]. *Garau et al.* showed that informed gaze improved participants' conversational involvement and the the feeling of naturalness, compared to random gaze and audio-only conditions [19]. For physical robots, *Sidner et al.* demonstrated on an interactive penguin robot that gaze by head turning is an effective communication technique [6]. They also studied the interaction effects between robot gestures and gaze on human-robot conversation. Additionally, gaze model for multiple people around a table is also explored, to determine the accuracy required of gaze to be recognized by experiment subjects [20].

In HRI, robot gestures are pursued in several lines of research. One line focuses on realizing robot gestures. *Okuno et al.* focused on robot gestures to give route directions [21]. Various novel methods for gestures generation have also been proposed [22], [23], [24]. As an example, *Ng et al.* propose a probabilistic model for speech and gesture synchronization [23]. They also explored varying model parameters to tune the degrees of expressiveness in robot gestures. Another research direction involves studying how robot gestures affect people's experiences and perception about robots. For instance, it is found that gestures positively influences participants' affect states [25] and improved engagement [26]. People's perception about robots is also studied when gestures mismatch the speech [24].

Speech is naturally a critical component in storytelling, The robot in [4] used a pre-recorded human voice to recite the story. Using speech synthesis, *Breazeal* proposes a framework to generate emotions such as happiness and fear for robot speech, and evaluated what emotions people perceive the generated speech belong to [7]. Further, *Theune et al.* propose a method for synthesizing expressive speech for storytelling [27] using prosodic rules. The study shows that people in general preferred the emotive speech over a neutral voice for communicating affects and suspense of stories.

III. Hypotheses

Different lines of research advance our knowledge about how verbal and non-verbal behaviors of a robot may influence people's task performance and social perceptions about robots. However, existing works on storytelling robots consider robot-only condition. It is not well understood if human-robot collaboration is a viable alternative, which may provide more compelling interaction. Beyond understanding what robot features contribute to compelling understanding, it is also important to understand the relative strengths of robot and human storytellers. The comparison not only provides the basis for improving HRC storytelling, but also guides the design of future robotic platforms for education and entertainment purposes. To this end, we have developed the following hypotheses:

TABLE I
SUMMARY OF EXPERIMENTAL PROCEDURE. RO DENOTES ROBOT RECITING STORY WITH GESTURE AND EYE CONTACTS. HRC DENOTES ROBOT NARRATES STORY AND PERFORM STORY SCENES WITH A PERSON

	Group I	Group II
Session 1	RO	HRC
Session 2	HRC	RO

1) HRC is an effective use of robots to augment traditional storytelling.

2) HRC storytelling is preferred by combining the strengths of both human and robot storytellers.

IV. METHOD

A. Participants

We recruited 60 secondary school pupils aged 14 to 15 to participate in the experiment. They were randomly divided into two equal groups, Groups I and II. We include a discussion about the limitation of the experiment participants in Section VI.

B. Procedure and Measures

The experiment consisted of one storytelling session each with HRC and RO storytelling settings respectively. Both sessions were 10 minutes in duration using the story - "Lamb to the Slaughter". In the RO session, the humanoid robot, Nao, acted as both a narrator and an actor. In the HRC session, a human storyteller performed the scenes while Nao narrates the story. Predefined actions of Nao were executed by a wizard-of-oz in synchronisation with the human performance. The storyteller used in the experiment had no professional experience in storytelling.

Both Groups I and II attended the two sessions in a classroom, shown in Figure 1. Group I attended RO storytelling, followed by HRC storytelling. Group II, first attended HRC storytelling, followed by RO storytelling. The experiment procedure is summarized in Table I.

Both groups received the same post-experiment survey. The question types included true-false questions, multiple-choice questions and free text responses. The participants were asked questions from the following categories:

1) *Demographic Questions and General Perception About Robots* (4 items) Participants answer general demographic questions about their age and gender. They indicate if they have any prior experiences with robots. Using a 5-point scale, they rate their general liking of robots.

2) *Evaluation of HRC Storytelling* (5 items) Participants rate how much they like the use of robots in storytelling. They report their preferences between HRC and RO storytelling. They then rate the effectiveness of HRC storytelling. Specifically, they indicate if they think robots improve storytelling as a narrator or actor.

3) *Comparison of Human and Robot Storyteller* (8 items) Participants report their preferences between the human and robot storyteller, as well as justify their preferences. They then consider if the robot or the human is more engaging for longer duration, and provide justification. They then comment in any specific ways they like and dislike the robot and human storyteller.

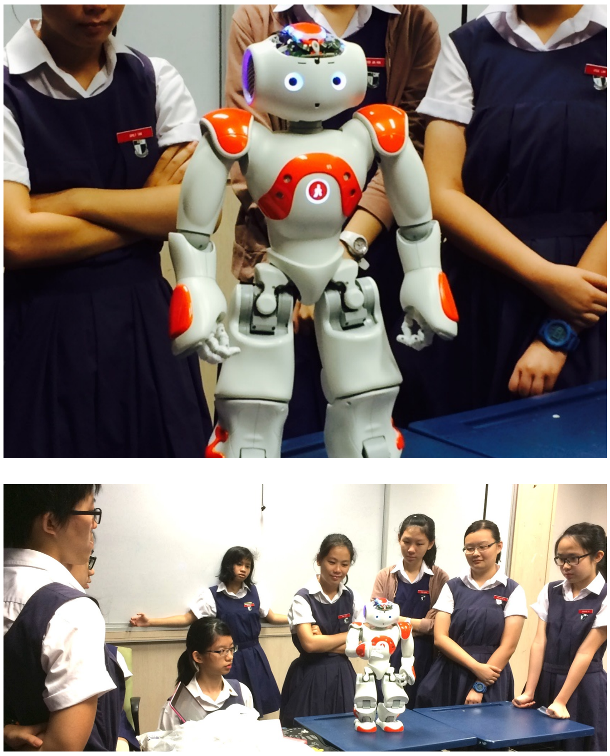


Fig. 1. Example Scenes from Experiment Session Setup

C. Robot Implementation

Nao was used to perform the story "Lamb to the Slaughter". The mystery genre was chosen to better capture listeners' attention [28]. Speech for the story was generated with Nao's TTS system. We incorporated different voice profiles to distinguish between male and female characters from the story. A neutral voice profile (the standard Nao voice) was used for the narration.

We implemented Nao's gestures using Choregraphe. We implemented gestures from deictic, iconic and metaphorical categories. Gesture examples included pointing, waving hands and putting (imaginary) things aside (for performing a story scene). Appropriate gestures were chosen based on timing and story context. Nao gestured every few seconds.

Similar to gestures, we hand-coded the robot gaze. We programmed Nao to turn its head to simulate eye contacts with listeners, and to simulate conversation with the human storyteller in HRC setting. We followed the algorithms in [4] for more natural eye contact. The robot interaction was scripted because the focus of our current work is not on gaze or gesture modeling and generation.

V. RESULTS

We present our results in the following sections. We first report results on participants' preference between HRC and

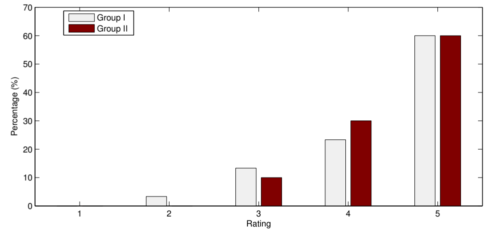


Fig. 2. Rating of Robot Storytelling. Subjects rated on a 5-point scale on how much they liked the use of robots in storytelling.

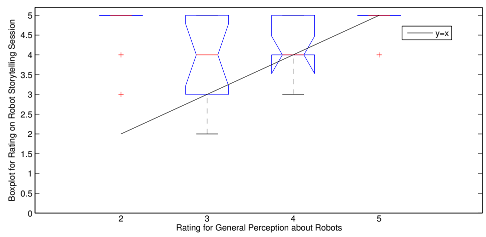


Fig. 3. Rating for General Perception on Robots Against Boxplot on Rating for Robot Storytelling Session. All boxplots are above the line y=x, suggesting the effectiveness or robot storytelling.

RO storytelling. We then present the subjects' preferences between the human and robot storyteller, followed by their justifications. The comparison identifies the respective strengths of the human and robot storyteller. Lastly, we assess how the participants' general perception about robots influences their preferences.

A. Robot Storytelling and Preferences

The participants' rating of how much they liked the use of robots in storytelling is shown in Figure 2. On a 5-point scale, 86.7% of the subjects rated their experiences positively (rating 4 or 5), with mean (M) 4.45 and standard deviation (SD) 0.79.

Compared to the participants' general perception about robots, the participants liked the storytelling robot significantly more. The result is summarized in Figure 3. The improved perception can be attributed to the aesthetic appeal of the robot, as well as its effective storytelling. The key features of robot storytelling are discussed in further detail in the following sections.

The subjects then indicated their preference between HRC and RO storytelling. 90% of the participants preferred HRC setting over RO setting. 90% of the subjects also considered HRC setting as an effective method for storytelling. The results are summarized in Figure 4. Specifically, 75% of the participants think that Nao improved storytelling as an actor, while 86.7% of the participants think that Nao improved storytelling as a narrator. We found no significant context effect that the order of the two storytelling sessions influenced the two groups' responses on the above questions. 83.3% of Group I preferred HRC storytelling compared to 96.7% from Group II, z=1.22, p>0.1.Similarly, 86.7% of Group I and 93.3% from Group II considered HRC storytelling effective.

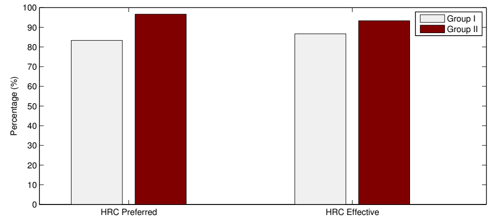


Fig. 4. Percentage of Participants Preferring HRC or Think HRC Effective

TABLE II
CROSS TABLE BETWEEN STORYTELLER PREFERENCE AND STORYTELLER CHOICE FOR LONGER-TERM ENGAGEMENT

Longer-term Engagement Choice	Human	Robot
Storyteller Preference		
Human	13	1
Robot	11	35

We therefore conclude that HRC is an effective method for storytelling and that it is preferred over RO storytelling.

B. Comparison of Human and Robot Storyteller

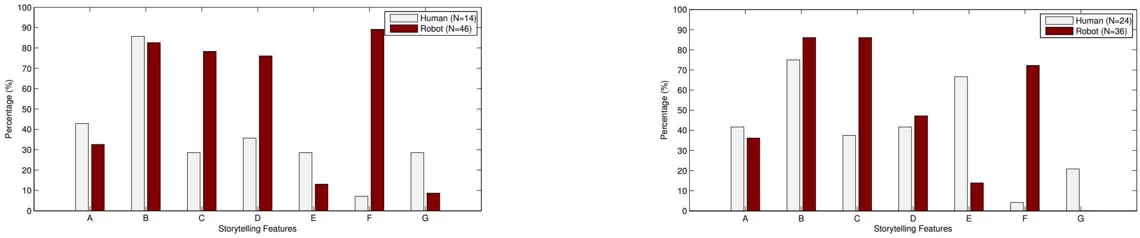
Within the HRC storytelling, 76.6% of the respondents preferred the robot storyteller over the human. The participants were asked to indicate if the robot or human storyteller is more engaging in longer-term. 60% of the subjects still chose the robot storyteller. We cross-tabulated the results in Table II. We found that the participants' preferences between the human and robot storyteller correlate strongly with their choices of storyteller for longer-term engagement, χ^2=24.45, p<0.001. The result suggests that preference of human storyteller significantly predicts the same choice for longer-term engagement at 93%. A similar result applies to preference of robot storyteller at 76%.

The participants were asked to justify their choices from a list of key storytelling features derived from existing literature, including 1) variation in tone, variation in pitch, frequency of gestures, types of gestures, gaze, and aesthetic appeal. They were also able to provide their own reasons. The results are shown in Figure 5. For each feature in favor of a particular agent, we compute the following value:

$$P_{feature,agent} = \frac{\#\ of\ votes\ on\ (feature, agent)}{\#\ of\ people\ voting\ agent}$$

The value measures the percentage of the participants who chose that particular reason, given all participants who chose that agent.

Figure 5a shows that the top feature in support of the robot storyteller is its aesthetic appeal, chosen by 90% of the participants preferring the robot storyteller. 82%, 78% and 76% of those participants also chose variation in pitch, frequency of gestures and type of gestures respectively to justify their preference. While aesthetic appeal may be considered



(a) Justification for Storyteller Preference: Human vs. Robot

(b) Justification for Longer-term Engagement: Human vs. Robot

Fig. 5. The Figure represents for each feature, the percentage of the participants who chose that feature, out of all participants who chose that feature to support either robot or human. A=Variation in Tone. B=Variation in Pitch. C=Frequency of Gestures. D=Types of Gestures. E=Eye Contacts. F=Aesthetic Appeal. G=Others

an extrinsic feature in storytelling, gestures and variation in pitch are integral components of storytelling. Only 15% of the subjects reported gaze as a reason for preferring the robot storyteller. The results match those from existing literature that gestures and gaze improve the participants' perception of the robot[3], [4], [6], [18]. though with varying degree of effectiveness in our experiment. To the best of our knowledge, the significance of variation in pitch (used to represent different story characters) has not been reported in previous works.

Figure 5b shows slightly different emphasis on storytelling features, as the participants were probed about which storyteller is more engaging in longer-term. 85% of the participants choosing robot storyteller consider variation in pitch and gesture frequencies as important features affecting longer-term engagement. The significance of aesthetic appeal dropped to 72%. The reversal is statistically reliable, indicating a shift away from novelty factors such as appealing robots. Though aesthetic appeal is still important for drawing the immediate attention of the participants, features integral to compelling storytelling matters in longer-term to effectively engage listeners.

The percentage difference for each feature in Figure 5 also suggests the perceived performance of the robot storyteller, compared against the human storyteller. The robot storyteller is considered better than the human storyteller for its appearances, and gesture frequencies. The robot is competitive with the human storyteller in gesture types and varied pitch. The human storyteller is better in terms of tones and eye contacts. Lastly, the percentages in the Other Category, whereby the subjects were able to give unlisted the reasons, suggest that 1) our list of features covers most key features in robot storytelling; and 2) there are other subtle features which the human storyteller is preferred. We present a more detailed discussion about the relative advantages of robot and human storyteller in Section VI.

C. *Prior Perception and Preferences*

70% of the participants had prior interaction with robots. We found that having prior interaction with robots did not influence the participants' preference over human or robot storyteller, χ^2=0.2801, p=0.5966. We also found no significant correlation between their liking of robot and their rating of the storytelling session, r=0.07. Similar to many previous works, the results suggest that the subjects' prior perception about robots does not influence significantly experiment outcomes.

VI. Discussion

Understanding how robots may best augment traditional storytelling, and the perceived performance of robot storyteller against human storyteller promise significant implications for designing future robotic platforms for education and entertainment purposes, The understanding also reveal areas of improvements in human-robot interaction. This work serves as a first attempt towards building such an understanding. To this end, we programmed a Nao robot to recite a story, and incorporated various features based on findings from existing literature to maximize its performance. We conducted the experiment whereby Nao either performed as an independent storyteller or collaborated with a human storyteller. From the post-experiment survey, we found that HRC storytelling is preferred over RO storytelling. We also identified the respective strengths of human and robot storyteller.

A. *Strengths of Human and Robot Storyteller*

A robot storyteller has significant advantages compared to a human storyteller due to its novelty and aesthetic appeal. Consistent with the results from Section V, 86% of the participants commented in the question "what do you like about robot storyteller?" that the robot is cool/cute. However, the advantage of aesthetic appeal drops when longer-term engagement is considered. In such context, features integral to storytelling, including gestures and speech, are considered more significant.

The results add to a growing body of evidence about the importance of robot gestures in shaping key outcomes human-robot interaction, such as engagement and perceived effectiveness. Many participants commented that the robot's frequent gestures sustained the level of interaction, while human storytellers may become tired and deliver inconsistent performance. One common scenario of inconsistent storytelling performance is parents telling stories to children at home. The comments are consistent with the result that gesture frequency was considered a strong advantages for robots in sustaining engagement in longer term.

Speech in storytelling presents a trade-off between human and robot storyteller. Though the robot is preferred for its varied pitch, and articulate speech, it lacks emotions and variation in tone appropriate to the development of a story, both of which a human storyteller is capable of. The trade-off may be resolved by improving the state-of-the-art in emotional speech generation, or by using pre-recorded voices from professional storytellers. However, speech generation may be preferred in practical applications of storytelling robots so that it could perform different stories without the need of recording human performances.

Lastly, human storyteller has clear strength in eye contacts and other subtle areas, such as the feeling of personal connection, and the ability to respond to impromptu questions from listeners. Robot storyteller lacks such capability to interact naturally with the audiences and respond to stimuli.

The above comparison reflects the complementary strengths of the human and robot storyteller, which could explain why HRC storytelling is preferred in our experiment. Both human and robots mitigate or lesson each others' shortcoming and limitations to deliver more compelling storytelling. Specifically, HRC improves storytelling by combining the consistency of robot performance and the interactivity from human storyteller.

B. Limitations

This work has one main limitation. Our findings are based on 60 girls aged 14-15, due to project constraints. The results may have limited generalizability. Further work is required to establish the extent to which they generalize to both genders and different age groups. Younger children may be ideal subjects as a significant amount of literature in education and psychology focuses on the impact of storytelling on them. As a preliminary study, we chose older children to better capture their responses and establish initial findings.

VII. Conclusion

Given the values of storytelling in children's skill development, as well as the increasing sophistication and accessibility of personal robots, we explored the question of how robots may be best used to augment storytelling. Building upon existing works, we tested human-robot collaboration in storytelling, as an alternative to robot-only storytelling. Our results showed that human-robot collaboration is an effective method for storytelling, and is preferred over robot-only performance. The experiment also allowed us to identify the relative strengths of human and robot storyteller, which is able to explain the preference of HRC. Our results lays the foundation for further exploration of HRC in educational and entertainment applications.

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