CreativeBot: a Creative Storyteller robot to stimulate creativity in children

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ABSTRACT

We present the design and evaluation of a storytelling activity between children and an **autonomous** robot aiming at nurturing children's creativity. We assessed whether a robot displaying creative behavior will positively impact children's creativity skills in a storytelling context. We developed two models for the robot to engage in the storytelling activity: *creative* model, where the robot generates creative story ideas, and the *non-creative* model, where the robot generates non-creative story ideas. We also investigated whether the type of the storytelling interaction will have an impact on children's creativity skills. We used two types of interaction: 1) Collaborative, where the child and the robot collaborate together by taking turns to tell a story. 2) Non-collaborative: where the robot first tells a story to the child and then asks the child to tell it another story. We conducted a between-subjects study with *103* children in four different conditions: *Creative collaborative, Non-creative collaborative, Creative non-collaborative and Non-Creative non-collaborative.* The children's stories were evaluated according to the four standard creativity variables: fluency, flexibility, elaboration and originality. Results emphasized that children who interacted with a creative robot showed higher creativity during the interaction than children who interacted with a non-creative robot. Nevertheless, no significant effect of the type of the interaction was found on children's creativity skills. Our findings are significant to the Child-Robot interaction (cHRI) community since they enrich the scientific understanding of the development of child-robot encounters for educational applications.

CCS CONCEPTS

• **Computer systems organization** → **Robotic autonomy**; • **Applied computing** → *Collaborative learning*; • **Human-centered computing** → **Empirical studies in HCI**; **Collaborative interaction**.

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KEYWORDS

human-robot interaction; child-robot interaction; social robots; storytelling; creativity; education

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1 INTRODUCTION

Creativity is one of the traits that differentiates humans from other species [22]. In the current technological and competitive world, creativity became an essential skill for an innovative working environment [32] as creative problem solving is regarded as a key pillar for managerial and entrepreneurial positions [22, 29]. Furthermore, scholars suggest the possibility of nurturing creativity throughout life [35]. Hence, arises the importance of developing creative skills since a very young age. Over the years, many researchers have tried to define creativity. Psychologists have presented at least 60 definitions of the term [5]. Despite the many definitions of creativity, there is a general consensus of two features typically associated with creativity: uniqueness and usefulness of an idea [28, 30].

Verbal creativity for children has always been linked to storytelling. Storytelling is an intellectual process that entails the creation and development of a story line and characters as well as the attribution of feelings and perceptions of time and space [17, 39]. Given its inherently social and creative nature, storytelling helps improving children's creativity skills as well as supporting their linguistic and affective development [33, 34]. Consequently, in this paper we aimed at stimulating children's creativity through a storytelling activity.

Previous studies demonstrate that children may mirror a robot's behavior such as curiosity [18], creativity [3] and growth mindset [27]. We investigate the same concept in this research by assessing whether an interaction with a creative robot will render children more creative. Similarly, previous research proposes that collaboration fosters more creativity [2, 3, 20]. Therefore, we also investigated whether designing our storytelling interaction in a collaborative manner will yield to higher creativity results in children. We designed the storytelling game as a turn taking game between the robot and the child in order to tell a story. Both of them provide ideas to the story (story continuations).

This work makes three contributions. First, **it is among the few works that uses an autonomous robot for a collaborative interaction with children implemented in a way that allows the robot to overcome speech recognition challenges**. Second, **it is following a new approach to stimulate children's creativity by making a child engage with a robot in a storytelling activity where the robot's additions to the story (i.e story continuations) are contextual (i.e are building on the child's story)**. As a third and final contribution, **we conducted a real-world study with 103 children and provide supported evidence that a robot's creative behavior encourages creative behavior from children.**

2 RELATED WORK

2.1 Evaluation of Creative Storytelling Systems

Margaret Boden, a pioneer in the area of computational creativity used for creating stories has distinguished between two types of creativity: 1) Historical creativity that includes ideas that have not occurred to anyone before and 2) Psychological creativity that involves ideas that have not occurred to a specific person before [8]. Therefore, creative autonomous systems must have access to a historical database of ideas. Otherwise, the creative system will only be capable of psychological creativity. Boden proposed the search of a conceptual space that is governed by a set of constructive rules to build an autonomous creative storytelling system. Stemming from Boden's work, Richtie proposed the evaluation of the creativity of a computational system using two criteria: novelty and quality [17].

A more recent approach that is more common nowadays suggests the evaluation of verbal creativity in terms of four criteria [19, 36, 38]: 1) Fluency: which denotes the number of ideas produced throughout the creative process 2) Flexibility: which denotes the variability of ideas generated.(i.e ideas addressing various topics or belonging to different categories) 3) Elaboration: which denotes the amount of details in describing the ideas. And 4) Originality: which denotes the surprising or uncommon element in generating an idea (also described as the "aha" moment) [21]. In our work, we opted for generating and evaluating creativity using these four variables in a storytelling interaction between a child and a robot.

2.2 Creativity in cHRI

Recently, scholars have introduced humanoid robots in creative activities with children. Alves-Oliveira has created the robot YOLO (your own living object) [6] capable of exhibiting social behaviors to be used as a tool or a character in stories created by children in a storytelling interaction. A recent study by Alves-Oliveira et.al [4] has proven that children who created their stories using the robot augmented by the social behaviors have demonstrated higher creative abilities in their stories than children who used the idle version of the robot.

Moreover, recent research has highlighted that socially interacting with a robot has a positive impact on children's creativity skills. Children who engaged with a creative robot in three one-to-one activities targeting constructional, figural and verbal creativity have expressed higher creativity throughout the interaction than children who engaged with a non-creative robot [2, 3]. Furthermore, children who interacted with a robot exhibiting positive feelings such as happiness and joy exhibited higher verbal creativity in stories that they told to the robot than children who interacted with a robot that portrayed negative feelings such as fear and anxiety [10].

With respect to storytelling interactions with a robot in order to improve creativity, a recent study has investigated the impact of collaborating with a wizard-ed robot exhibiting creative versus non-creative behavior on children's creativity skills [13]. In contrast with previous research, children who interacted with the creative robot did not exhibit higher creativity than children who collaborated with the non-creative robot. The authors suggested as a possible interpretation of the results that children exhibited frustration to the robot's non-contextual interference to their stories regardless of the condition. In this work, we build on previous work by using an autonomous robot that provides contextual story continuations to the children's input.

2.3 Storytelling in cHRI

Robots have been a popular tool in storytelling activities for children. In [15], the authors proposed an architecture that enables a robot to learn from an interactive storytelling game with a child and at the same time teach the child information collected from previous interactions. In another Wizard-of-Oz study [37], researchers have explored the insertion of contextual versus non-contextual story content by the robot in a collaborative storytelling interaction with children. The first strategy encouraged younger children to speak more. Nevertheless, although the first strategy introduces higher cognitive load, children equally enjoyed the interaction in both conditions. Furthermore, Jacqueline Kory-Westlund et.al conducted a series of studies with robots and children in a storytelling context. For instance, in [24], they explored the effects of matching the robot's language proficiency and development for 8 sessions over two months on children's learning performance. Whereas, in [23], they explored the effects of 1) having a background story about the robot and 2) the robot entraining the pitch of its speech to the children's on children's rapport with the robot as well as their learning performance.

It is worth noting that previous studies entailing collaborative storytelling interactions between a robot and a child were mostly tele-operated. In this work, we implemented the robot's behavior as fully autonomous. The system is developed in a manner that allows the robot to use specific keywords to be able to generate story continuations that overcome poor speech recognition performance with children.

3 METHODOLOGY

3.1 Conditions

Researchers have not yet investigated mirroring creativity in a storytelling setting between a child and an autonomous robot in cHRI. In [2, 3, 13, 20], authors propose that the nature of the activity as collaborative versus competitive may alter the level of children's creativity throughout the activity. Therefore, we designed the conditions in our interaction to evaluate the effects of different types of interactions as well as different levels of the robot's creativity on children's creative processes. The conditions are presented in details in Table 1.

Table 1: Experimental conditions.

	Collaborative C	Non-collaborative NC
Creative C	**CC:** The child and a creative robot take turns to create a story.	**CNC:** The robot tells a creative story to the child and then asks the child to tell it a story back.
Non-creative NC	**NCC:** The child and a non-creative robot take turns to create a story.	**NCNC:** The robot tells a non-creative story to the child and then asks the child to tell it a story back.

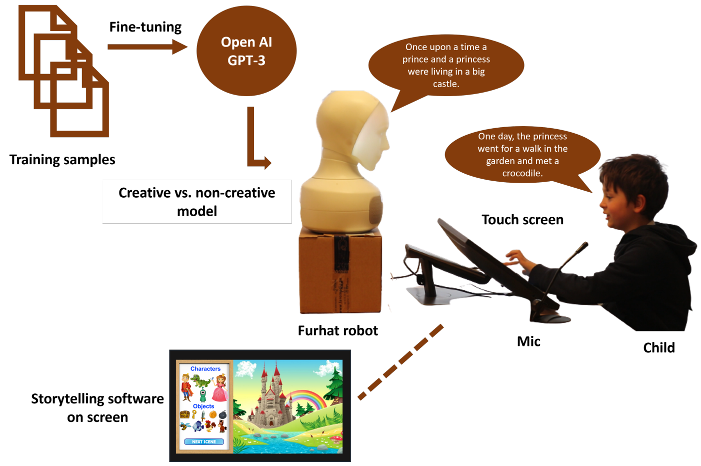


Figure 1: Flow schematics of the interaction between a child and a robot in our storytelling activity.

3.2 Research Questions and Hypotheses

We addressed three research questions:

RQ1. How will the creative behavior of the robot impact children's creative abilities in a storytelling interaction?

Based on previous research where children showed higher creativity skills when interacting with a creative robot than a non-creative robot [2, 3], we hypothesised that children in the creative conditions will exhibit higher creativity in their generated stories than children in the non-creative conditions. **(H1)**

RQ2. How will the collaborative nature of the interaction impact children's creative abilities in a storytelling context?

The literature suggests that collaborative interactions lead to higher creativity than competitive or non-collaborative interactions [20]. Therefore, we hypothesized that children in the collaborative conditions will exhibit higher creativity than children in the non-collaborative conditions. **(H2)**

RQ3. How will children perceive the robot in terms of likeability and intelligence in the creative versus non-creative conditions and in the collaborative versus non collaborative conditions?

The robot is using short non-invested and non-original clauses in the non-creative conditions versus elaborated and novel ideas in the creative conditions. Therefore, we hypothesize that children will perceive the robot as more likeable **(H3.1)** and smarter **(H3.2)** in the creative conditions than in the non-creative conditions. The robot in the collaborative conditions is interactive and is listening to the children's input and building on it. Consequently, we hypothesize that children will like the robot more **(H3.3)** and perceive it as more intelligent in the collaborative versus non-collaborative conditions. **(H3.4)**

4 SYSTEM DESIGN AND IMPLEMENTATION

Figure 1 explains the design of our storytelling interaction that was structured as a one-to-one interaction between a child and a robot.

We used the Furhat [1] robot in our collaborative game. Furhat [1] is a virtual face back projected on an embodied robotic head. The robot is capable of displaying head movements, eye gaze behavior and facial expressions. Due to the storytelling nature of our interaction, we selected Furhat as our robot due to its expressivity. We implemented two models to generate the robot's creative versus non-creative behavior. The interaction between the child and the robot was mediated by a storytelling software interface that the child used in order to facilitate the storytelling process to inspire more ideas and render the game more interactive.

4.1 Robot's Cognitive Behavior

We generated the behavior of the robot by fine-tuning the Open AI GPT-3 model[2] [16] to create two models that produce creative versus non-creative story continuations. We used training data provided by our two previously conducted studies between a robot and children in a storytelling setting [11, 13] to fine-tune our models. The creativity was generated utilising the four creativity variables: fluency, flexibility, elaboration and originality. We then assessed the viability of the two models for the purpose they were created for. 10 stories were generated between a human and the creative and non-creative models (5 for each). 26 participants evaluated the creativity of the model in each story on a scale from 1 (extremely non-creative) to 5 (extremely creative). We administered a one-way Anova parametric test using the condition (creative vs. non-creative) as our independent variable and the creativity score as the dependent variable. Results have shown that the creative model was perceived as significantly more creative than the non-creative model (*Creative:* $M = 3.36$, $SD = 0.98$, *Non-creative:* $M = 2.84$, $SD = 1.1$, $p < 0.001$). We refer to a parallel publication for more details about the models and their assessment [12]. The stories used in the non-collaborative conditions as well as sample stories created between the robot and the child in the collaborative conditions are illustrated on Figure 2.

In the collaborative conditions, we implemented the system in a way that overcomes speech recognition challenges with children. The robot behaved in a manner that allows it to ignore the irrelevant

[1] https://furhatrobotics.com/

[2] https://beta.openai.com/

words and choose keywords relevant to the theme from the child's input to generate the next story continuations. Our approach to erroneous speech recognition enabled stories in most of the cases to preserve the context. Situational examples of the robot's behavior in case of poor speech recognition is provided in Table 2.

Table 2: Samples of erroneous speech recognition.

Child's input	Erroneous speech recognition(what the robot heard)	The robot's response to the erroneous speech recognition
Then the alien came from outer space.	Ben 10 alien came from outer space.	The alien wanted to kill the prince with the sword.
But the prince had a pet bee which helped him.	But the prince had a pet fee with Stelton.	The alien was scared! -the alien was initially going to attack the prince.-

4.2 Storytelling Software Interface

We have modified our previously implemented storytelling software [11, 13] developed using the Unity game engine [3]. The theme for the software is a fairy tale castle. The game consists of three different scenes around the castle and the castle's garden. Children have the chance to select between 4 different characters and 9 objects in order to narrate the story either with the robot or to the robot as per the assigned condition. The software interface is displayed on a touch screen that enables the children to move the characters and objects all around the scene while telling the story.

5 SYSTEM EVALUATION

5.1 Participants

We required English proficiency since our models were trained on English language data and therefore, we recruited 103 participants from 3 British international schools in Stockholm (*M = 54, F = 49*). Children's age ranged from 7 to 9 years (*M = 7.88, SD = 0.77*). We excluded data from 10 students due to missing data, children speaking to the robot in other languages than English or children who did not interact with the robot. Our analysis then entailed data from 93 children (*Condition 1 CC = 24, Condition 2 NCC = 23, Condition 3 CNC = 23, Condition 4 NCNC = 23*).

5.2 Pre-test

Children may inherently have different creativity levels [14]. Thus, an exclusive analysis of children's creativity skills in the storytelling interaction is biased. To eradicate this issue, we performed a creativity pre-test to evaluate children's creativity levels prior to the storytelling game. We then calculated the children's creativity scores and ensured that the scores are similar for the four different experimental groups. Table 3 clarifies the creativity scores per condition as well as the balanced assignment for gender, age and number of participants per experimental group. It is worth noting that in the fourth condition (NCNC) the number of male users was almost double the number of female users. We argue that this imbalance is peripheral since the initial creativity score of this experimental condition is not remarkably different from the other experimental conditions.

We conducted the creativity pre-test (consisting of the Droodle creativity task and the unusual uses creativity task) and evaluated it based on the procedures provided in [21].

Condition	N	Gender	Age	Creativity scores
CC	24	Male = 12, Female = 12	M = 7.83, SD = 0.7	M = 3.1, SD = 0.72
NCC	23	Male = 12, Female = 11	M = 7.96, SD = 0.77	M = 2.8 , SD = 0.74
CNC	23	Male = 12, Female = 11	M = 8.13, SD = 0.92	M = 3 , SD = 0.89
NCNC	23	Male = 15, Female = 8	M = 7.7, SD = 0.7	M = 2.91, SD = 0.79

Table 3: Experimental conditions assignments balanced with respect to gender, age and creativity level scores.

5.3 Procedures

The study procedures and data collection were approved by the local institution. Two weeks preceding the study, we sent information sheets and consent forms to the children's legal guardians. The data was later analysed and published according to the legal guardians' permissions.

We conducted our study at the school premises in an empty and isolated room. One experimenter was present in the room to aid the children in case of inquiries or arising technical difficulties. The robot and the screen were placed on a table in front of the child. The touch screen was in the middle between the child and the robot. To be able to perform our data analysis, we audio and video recorded the interactions.

As soon as the child entered the room, the experimenter greeted her, collected demographic data (age and gender) and briefed her about the interaction. The experimenter then administered the creativity pre-test and then let the child interact with the robot. The experimenter did not interfere unless requested by the child. The robot started by greeting the child and explaining the game. The interaction was freely timed and thus, in the four conditions, the child was able to end the interaction whenever she wanted by uttering the word "The end". The duration of the interaction ranged from *5* to *25* minutes. At the end of the interaction, the child answered a short questionnaire about her experience with the robot and the storytelling game. Finally, the experimenter thanked the child and ended the encounter.

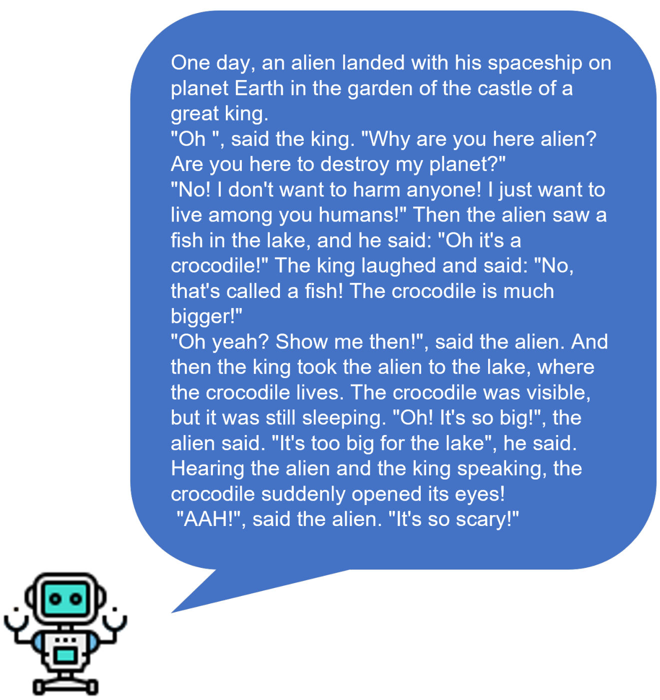
5.4 Measures

5.4.1 Objective Measures. To address our research questions, we developed a coding scheme to assess children's creative abilities throughout the storytelling interaction as per the guidelines highlighted in [26]. We transcribed the child's speech from the audio

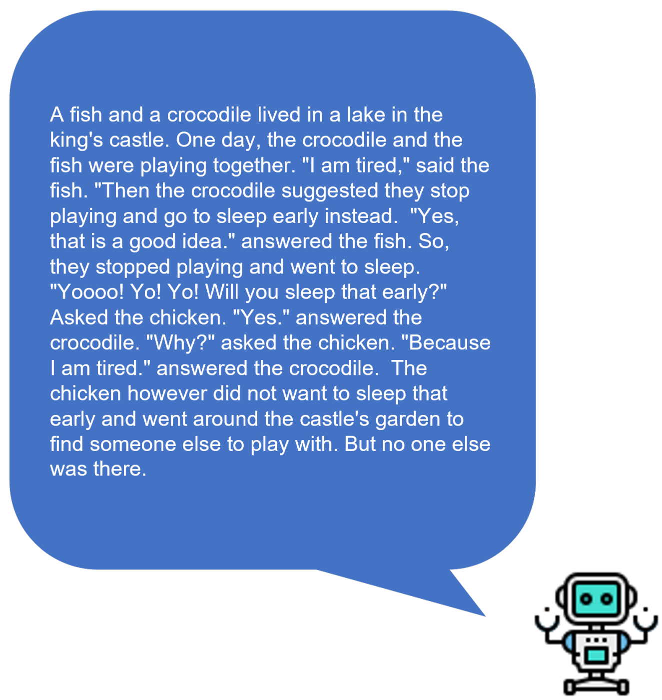
[3]https://unity.com/

(a) **Condition 1: Creative Collaborative.**

(b) **Condition 2: Non-creative Collaborative.**



(c) **Condition 3: Creative Non-collaborative.**



(d) **Condition 4: Non-creative Non-Collaborative.**

Figure 2: Sample stories generated in the four different conditions.

Table 4: Coding scheme to measure children's creativity skills during the storytelling encounter.

Creativity Variable	Definition
Fluency	Fluency is counted as the total number of story elements used by the child.
Flexibility	Flexibility is counted as the number of different categories that were addressed in the child's story.
Elaboration	Elaboration -elaborated details in the child's story– is calculated as the difference between the total number of words used and the total number of story elements per child (fluency value).
Originality	Each idea was rated on a three-point scale: 1 = low, 2 = medium and 3 = high. The total level of originality per child is calculated as the average of originality of all the ideas produced by the child.

files starting from the first word that the child uttered in the story. In case the audio file was not available, was corrupted or inaudible, we analysed the video file instead. In alignment with the creativity criteria used for generating the robot's creative behavior, we measured children's creativity skills through the four recognised measures: fluency, flexibility, elaboration and originality [19, 36, 38]. In our context, we defined the four variables as per Table 4.

Using the developed coding scheme, we performed behavioral coding analysis to assess our measures. Two coders double-coded *20%* of the data assigned randomly as recommended in [9] to ensure the validity of our coding scheme. The two coders had an average inter-rater agreement of *89.5%* denoting high agreement (ranging from *80%* to *97%* for the different creativity measures). Consequently, the data was divided randomly and equally between the two coders who finalised the behavioral analysis.

5.4.2 Subjective Measures. We used an adapted version of the Godspeed [7] questionnaire to measure children's engagement with the robot. We assessed measures of likeability of the robot, likeability of the storytelling game, perceptions of the robot's intelligence and likeability of the robot's story ideas. Children answered this questionnaire using a 5 point Likert scale Smily-O-Meter [31] to render it easier for the children to respond to.

6 RESULTS

For RQ1. and RQ2., we realised that our sample followed a non-normal distribution by running a Shapiro-Wilk (S-W) normality test for all our considered variables (displayed in Table 4). Thus, we followed the conventional process of applying a log transformation to our sample to normalise the data [25].

6.0.1 RQ1. **How will the creative behavior of the robot impact children's creative abilities in a storytelling interaction?**

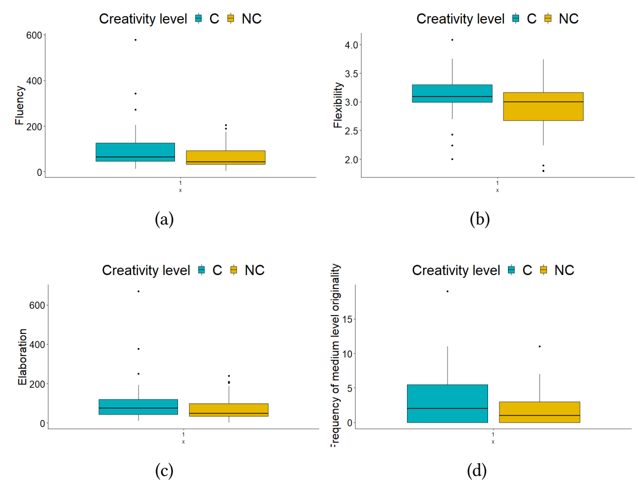


Figure 3: a) Children in the creative conditions were more fluent than children in the non-creative conditions (p<0.01). b) Children in the creative conditions were more flexible than children in the non-creative conditions (p<0.05). c) Children in the creative conditions were more elaborated than children in the non-creative conditions (p<0.05). d) Children in the creative conditions used more medium originality ideas than children in the non-creative conditions (p<0.05).

After applying the log transformation to ensure that our sample follows a normal distribution, we administered a one-way Manova parametric test for our statistical analysis. We used the creativity level (creative vs. non-creative) as our independent variable and the four creativity measures (fluency, flexibility, elaboration and originality) as our dependent variables. Below we summarize the results for our dependent variables [4]:

(1) **Fluency:** results showed a significant effect of the robot's creativity level on children's fluency (*p<0.01 , M = 83.68, SD = 79.67*). Children assigned to the creative conditions (*M = 100.12, SD = 96.38*) significantly used more story elements than children assigned to the non-creative conditions (*M = 66.87, SD = 53.94*). See Figure 3(a).
(2) **Flexibility:** we found a significant effect of the robot's creativity level on the flexibility expressed by children while telling their stories (*p<0.05, M = 3.02, SD = 0.41*). Children in the creative conditions (*M = 3.12, SD = 0.37*) used higher variety of ideas (i.e ideas covering various categories) than children in the non-creative conditions (*M = 2.92, SD = 0.44*). See Figure 3(b).
(3) **Elaboration:** the robot's creativity level had a significant effect on children's elaborated details in the story ideas they provided (*p<0.05, M = 88.45, SD = 87.7*). Children were significantly more elaborate in the creative conditions (*M = 102.91, SD = 107.6*) than in the non-creative conditions (*M = 73.67, SD = 58.73*). See Figure 3(c).

[4] Reported mean and standard deviation values are calculated from raw data before applying the log function.

(4) **Originality:** no significant effect was found of the robot's creativity level on the average originality exhibited by a child in the storytelling process. We also analysed the effect of the creativity level of the robot on the frequency of ideas of each originality level (low, medium and high). Only a significant effect of the robot's creativity level on children's medium originality level ideas was noticed (*p<0.05, M = 2.68, SD = 3.27*). We observed that children in the creative conditions (*M = 3.49, SD = 3.93)* significantly expressed more medium level ideas than children in the non-creative conditions (*M = 1.85, SD = 2.17*). See Figure 3(d).

Based on our findings, children who interacted with the creative robot expressed higher creativity in terms of fluency, flexibility, elaboration and frequency of medium level originality ideas than children who interacted with the non-creative robot. Hence, we conclude that **H1** is almost fully supported.

6.0.2 *RQ2.* How will the collaborative nature of the interaction impact children's creative abilities in a storytelling context?

Following the same procedure for *RQ1.*, we ran a Manova parametric test for our statistical analysis for *RQ2.*. The type of interaction (collaborative vs. non-collaborative) was our independent variable and the four creativity criteria (fluency, flexibility, elaboration and originality) as our dependent variables. No significant effect was found of the type of interaction on our dependent variables [5]: fluency (*p = 0.64, Collaborative: M = 90.77, SD = 95.55, Non-Collaborative: M = 76.43, SD = 59.48*), flexibility (*p = 0.36, Collaborative: M = 2.99 =, SD = 0.48, Non-Collaborative: M = 3.05, SD = 0.34*), elaboration (*p = 0.42, Collaborative: M = 101.89, SD = 109.86, Non-Collaborative: M = 74.72, SD = 54.84*), originality (*p = 0.61, Collaborative: M =1.33, SD = 0.32, Non-Collaborative: M = 1.3, SD = 0.3*).

To conclude, there was no significant effect of the type of interaction (collaborative vs. non-collaborative) on children's creativity skills (fluency, flexibility, elaboration and originality). Hence, **H2** is rejected.

6.0.3 *RQ3.* How will children perceive the robot in terms of intelligence and likeability in the creative versus non-creative conditions and in the collaborative versus non-collaborative conditions?

Similar to the procedure followed with the objective measures, we ran a Shapiro-Wilk (S-W) normality test to assess the normality of our data. Likewise, our subjective measures were not normally distributed. Applying the log transformation did not alter the data distribution and therefore, we decided to apply a series of the Wilcoxon signed-rank non-parametric test. In one instance, we used the creativity level (creative vs. non-creative) as our independent variable; and the likeability of the game, the likeability of the robot, the perceived intelligence of the robot and the likeability of the robot's story ideas as dependent variables. In the other instance, we used the same dependent variables while our independent variable was the type of interaction (collaborative vs. non-collaborative).

Creativity level as independent variable:

No significant effect was found of the creativity level on both the likeability of the storytelling game and the likeability of the robot. Nevertheless, results highlight a significant effect of the creativity level on the perceived intelligence of the robot (*p<0.05, M = 4.38, SD = 0.89*) and the likeability of the robot's story ideas (*p<0.05 , M = 4.27, SD = 0.92*). The robot was significantly perceived as smarter in the creative conditions (*M = 4.62, SD = 0.67*) than in the non-creative conditions (*M = 4.14, SD = 1.02*). Furthermore, children significantly liked the robot's ideas in the creative conditions (*M = 4.5, SD = 0.68*) than in the non-creative conditions (*M = 4.04, SD = 1.06*). See Figure 4(a) and 4(b).

Type of interaction as independent variable:

We found no significant effect of the type of the interaction on both the likeability and the perceived intelligence of the robot. However, a significant effect was found of the type of interaction on the likeability of the storytelling game (*p<0.05, M = 4.27, SD = 0.82*) and the likeability of the robot's story ideas (*p<0.05, M = 4.27, SD = 0.92*). Children significantly liked the game more in the non-collaborative conditions (*M = 4.42, SD = 0.8*) than in the collaborative conditions (*M = 4.1, SD = 0.83*). Moreover, children significantly liked the ideas of the robot more in the non-collaborative conditions (*M = 4.49, SD = 0.78*) than in the collaborative conditions (*M = 4.02, SD = 0.1*). See Figure 4(c) and 4(d).

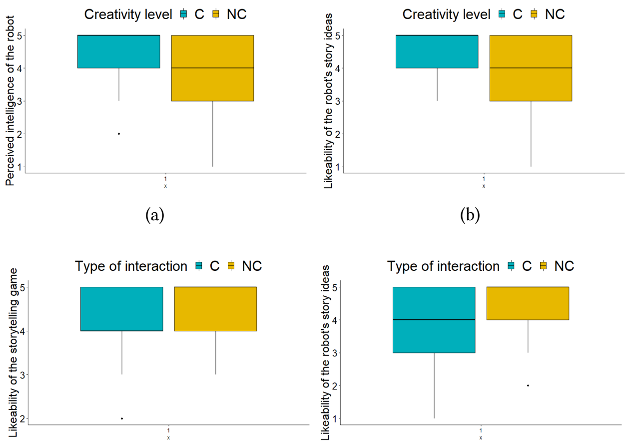
To summarize, results have shown that there was no significant effect of the creativity level on the likeability of the robot. Whereas, children perceived the robot as significantly smarter in the creative conditions than in the non-creative conditions. Therefore, **H3.1** is rejected while **H3.2** is supported. Furthermore, we did not find a significant effect of the type of interaction on both the likeability of the robot and its perceived intelligence. Thus, both **H3.3** and **H3.4** were not supported.

7 DISCUSSION

7.1 Effect of the robot's creativity level on children's creativity skills (RQ1.)

In a similar previous study [13], the authors investigated the effects of changing the robot's creativity level on children's creativity skills in a collaborative storytelling setting. Children were asked to collaboratively tell a story together with the robot. So whenever the robot or the child has a new idea, they will tell it to each other. In one condition, the robot told creative ideas. In the other, the robot told non-creative ideas. In that previous study, the robot was wizard-ed and therefore, a human operator chose between a pool of limited ideas for the robot to tell to the child in the storytelling game. This resulted in the story ideas being non-contextual (i.e do not fit or relate well) to the child's story. No significant effect was found of the robot's creativity level on children's creativity skills. In contrast, in this paper, we chose to implement the robot's behavior as autonomous and contextual. The robot listens to the child's idea and then builds on it. To avoid confusion, in the collaborative conditions, we designed the interaction such that both the robot and the child take turns one by one in order to contribute with an idea to the story. Due to the changes executed in our work and in line with our initial hypothesis, children who played the game with the creative robot expressed higher creativity (in terms of fluency, flexibility, elaboration and frequency of medium level originality

[5] Reported mean and standard deviation values are calculated from raw data before applying the log function.



(a) (b) (c) (d)

Figure 4: a) Children in the creative conditions perceived the robot as smarter than in the non-creative conditions (p<0.05). b) Children in the creative conditions liked the robot's story ideas more than children in the non-creative conditions (p<0.05). c) Children in the non-collaborative conditions liked the game more than children in the collaborative conditions (p<0.05). d) Children in the non-collaborative conditions liked the robot's story ideas more than children in the collaborative conditions (p<0.05).

ideas) than children who played the game with the non-creative robot. Nevertheless, children did not express higher average originality in the creative conditions than in the non-creative conditions. This result suggests that children interacting with the robot that used more story elements, more elaborated details and whose ideas covered more aspects were more eager to generate more ideas and cover more aspects regardless of whether their ideas were highly original or not (even if the robot was using original ideas).

7.2 Effect of the type of the interaction on children's creativity skills (RQ2.)

Contrary to our hypothesis, we found no significant effect of the type of interaction on children's creativity skills. The literature [2, 3, 20] suggests that collaborative activities foster more creativity. Thus, our findings may be explained by the degree of collaboration in the interaction. In our work, we had a collaborative versus a non-collaborative condition. Instead, having a competitive versus a collaborative condition may yield to different results.

7.3 Children's perceptions of likeability of the game and the robot (RQ3.)

Generally, children's perceptions of likeability of the game, the robot and the robot's story ideas per experimental condition were quite high ranging from *4.02* to *4.5* on a scale from 1 to 5 (where 1 means did not like it at all and 5 means liked it very much). These high perceptions suggest the great potential of our system in advancing children's education. The robot was also generally perceived as highly intelligent. The perceived intelligence variable ranged between *4.13* and *4.62* on a scale from 1 to 5 (where 1 means not smart at all and 5 means extremely smart). Most of the children who played the game with the robot have not interacted with robots before. Interacting with a robot that listened to them and responded accordingly clearly exceeded their expectations and hence, explains the high scores of the children's perceived intelligence of the robot.

As hypothesized, children in the creative conditions significantly perceived the robot as more intelligent and significantly liked the robot's ideas more than in the non-creative conditions. As explained in Section 4.1, the robot in the creative conditions used more words, invested clauses, elaborate details and original ideas. Therefore, children perceived it as smarter and liked its ideas more than in the non-creative conditions.

Nevertheless, we initially hypothesized that children's perceptions of likeability of the robot and the perceived intelligence of the robot will be higher in the collaborative conditions than in the non-collaborative conditions. In the collaborative conditions, it is clearer to the children that the robot is listening to them and responding accordingly. In contrast to our hypothesis, children liked the game more and perceived the robot as smarter in the non-collaborative conditions than in the collaborative conditions. We attribute this result to the fact that in the collaborative conditions the robot is exposing itself more. In other words, in both collaborative and non-collaborative conditions, children assume that the robot is listening to them. However, in the collaborative conditions, the erroneous speech recognition increases the chance of the robot's irrelevant output. In the non-collaborative conditions, the process was more controlled where the robot will tell a pre-prepared story and then remain silent while children are telling their story.

8 CONCLUSION AND FUTURE WORK

This work is among the rare attempts to design and evaluate a collaborative interaction between a child and an autonomous robot. We investigated the effects of varying the robot's creativity level (creative vs. non-creative) and the type of the interaction (collaborative vs. non-collaborative) on children's creativity skills. Our results suggested that interacting with a creative robot resulted in the children expressing higher creativity than interacting with a non-creative robot. Furthermore, generally, the children positively perceived the game and the robot.

For the purpose of this research, we primarily used speech as the mode of interaction. The robot did not express facial expressions in our study but it exhibited eye gaze that followed the child constantly. As an aspect of multi-modality, we suggest that in the future combining our storytelling activity with emotional facial behavior from the robot will yield a positive impact on children's creativity skills. Moreover, we found no significant effect of the type of the interaction on children's creativity skills. Hence, in the future, we plan to extend the work by assessing the results in case of having a collaborative versus a competitive type of interaction (instead of collaborative vs. non-collaborative). We further plan to investigate ordering effects on children's creativity skills (i.e effects of introducing the story elements first by the robot versus the child).

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