“And then what happens?” Promoting Children’s Verbal Creativity Using a Robot

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***Abstract*—While creativity has been previously studied in Child-Robot Interaction (cHRI), the effect of regulatory focus on creativity skills has not been investigated. This paper presents an exploratory study that, for the first time, uses the Regulatory Focus Theory (RFT) to assess children’s creativity skills in an educational context with a social robot. We investigated whether two key emotional regulation techniques, promotion (approach) and prevention (avoidance), stimulate creativity during a storytelling activity between a child and a robot. We conducted a between-subjects field study with 69 children between the ages of 7 and 9 years old, divided between two study conditions: (1) promotion, where a social robot primes children for action by eliciting positive emotional states, and (2) prevention, where a social robot primes children for avoidance by evoking a states related to security and safety associated with blockage-oriented behaviors. To assess changes in creativity as a response to the priming interaction, children were asked to tell stories to the robot before (pre-test) and after (post-test) the priming interaction. We measured creativity levels by analyzing the verbal content of the stories. We coded verbal expressions related to creativity variables, including fluency, flexibility, elaboration, and originality. Our results show that children in the promotion condition generated significantly more ideas, and their ideas were on average more original in the stories they created in the post-test rather than in the pre-test. We also modeled the process of creativity that emerges during storytelling in response to the robot’s verbal behavior. This paper enriches the scientific understanding of creativity emergence in child-robot collaborative interactions.**

***Index Terms*—creativity, regulatory focus, social robots**

I. Introduction

Creativity is an inherent human trait that is highly prized in the 21st century [1], [2]. Creativity in children facilitates critical thinking, self-expression and communication [3]. Since social robots are more present in educational settings as children’s companions, researchers have investigated their effectiveness in stimulating children’s creativity [4], [5]. Previous work has shown that robots with embedded creativity skills prompt children to be more creative [6]. Also, there is evidence that children’s creativity is influenced by different factors, such as the activity, environment, and a robot’s verbal and non-verbal behaviors [7], [8]. Therefore, the way robots’ behaviors and creativity tasks are designed is crucial.

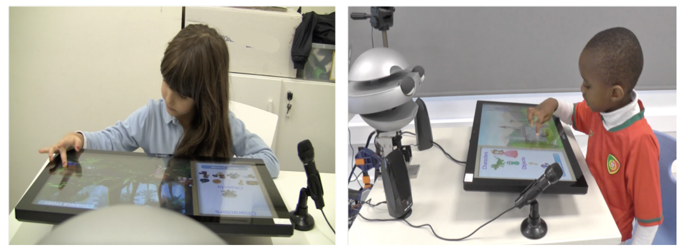


Fig. 1: Children engaging with the interactive storytelling activity using a teleoperated robot to stimulate verbal creativity.

Moreover, our creativity is generally not stable and can fluctuate due to other variables. For example, our emotions related to specific moods can deeply influence our creativity [9]. Nonetheless, the literature is still inconclusive: some studies suggest that positive moods can enhance creativity compared to other emotional states [9], but other studies indicate that a negative mood can motivate people to find more creative solutions to return to a neutral mood [10].

Regulatory Focus Theory (RFT) describes two motivational systems to explain goal attainment: promotion and prevention. A promotion focus is concerned with accomplishment as a desired end state and is associated with moods that reflect an approach orientation (e.g., happiness). A prevention focus involves safety as a desired end state, and its moods are related to avoidance (e.g., fear) [11], [12]. In this study, we extend previous investigations of the influence of regulatory focus on creativity [13] to account, for the first time, for cHRI. We conducted a study in two primary schools for two consecutive weeks (Figure 1). We used a social robot to prime different emotional states associated with regulatory focus moods (i.e., happiness and fear). *Our key insight from this work is that a social robot can influence children’s emotional states and affect their ability on creative tasks.* In a between-subjects design, we

*Both authors contributed equally to this research primed children under a *promotion condition*, which motivates approach actions and elicits positive emotional states, and a *prevention condition*, which motivates less risk-taking and safer, more guarded moods associated with avoidance. We then studied their creativity during storytelling interactions with a robot according to the emotional state that was stimulated.

This work makes two main contributions. First, **it is the first experimental study conducted in the field that explores the use of RFT to investigate children's verbal creativity with robots**. We designed an interactive application where children engage in a storytelling activity with a robot that displays verbal and non-verbal behaviors according to the course of the interaction. As our second contribution, **we provide empirical evidence that emotional states associated with regulatory focus affect children's verbal creativity**. More precisely, our quantitative and descriptive results indicate that promotion enhances creativity skills, but prevention does not necessarily inhibit it. As such, this research provides new insights and raises questions into robot behavior design where creativity is a key element of task performance in real-world environments.

II. Related Work

A. Background on Creativity

No single definition encapsulates creativity; in the field of psychology alone, researchers have derived at least 60 definitions of the term [14]–[16]. In their systematic review, Alves-Oliveira et al. summarized some of the most common definitions of creativity spanning a fifty-plus year timeline [16]: creativity definitions presented begin with Guilford's definition (1967) of creativity ("a behavior characterised by three creativity metrics known as fluency, flexibility and originality" [17]) and end with Cronin and Loewenstein's definition (2018) ("the process of creating inventions by following cues to develop insights that shift our perspectives" [18]).

Research describes different types of creativity, as well: (1) figural creativity, related to the development of visual artifacts (i.e., drawing, painting, sketching) [19], (2) performance creativity [20], related to the creation of performance arts (i.e., music, dance, theater), (3) constructional creativity [4], which represents building and tinkering (e.g., using LEGO blocks), and (4) verbal creativity, related to the verbal presentation of ideas and thoughts (i.e., writing, storytelling, poetry) [19].

In our work, we focus on verbal creativity usually assessed by four criteria [17], [21], [22]: 1) Fluency: denotes the number of ideas produced throughout the creativity process. 2) Flexibility: denotes the various distinctive aspects covered by the ideas generated. 3) Elaboration: denotes the amount of elaborated details in the ideas produced. 4) Originality: refers to the novel and surprising element introduced by the ideas.

B. Regulatory Focus Theory

Higgins' RFT [23] distinguishes between two motivational approaches to self-regulation, promotion and prevention. Promotion is characterized by the anticipation of positive outcomes as a motivation to achieve a goal. In contrast, prevention is characterized by the avoidance of negative outcomes as a motivation to achieve a goal [12].

Research suggests that the relationship between goal attainment and emotional experiences is influenced by regulatory focus [11]. A promotion focus paradigm is associated with feelings of excitement that culminate in happiness when the goal is attained. A prevention focus paradigm is associated with feelings of fear that culminate in relief when the goal is attained [9]. Previous research demonstrated that the promotion-focused approach, associated with positive emotional states, stimulated higher creativity in humans than the prevention-focused approach associated with negative emotional states [9], [24].

RFT has rarely been addressed in Human-Robot Interaction (HRI). Some studies investigated the concept of *regulatory fit* [25] by matching the regulatory focus type of a robot to the user's. Participants who interacted with a robot that matched their regulatory focus type engaged in longer interactions [26], perceived the robot as more persuasive [27] and performed better on a Stroop test [28] than those who did not. Some cHRI studies investigated the effects of RFT on children interacting with a social robot. Researchers found that children in the prevention condition perceived the robot as more likeable than those assigned to the promotion one [29]; the authors suggested as a possible interpretation that the robot expressed more vulnerability (i.e., fear) in the prevention condition, leading children to perceive it as more likeable and relatable. Nevertheless, children assigned to the promotion condition expressed more happiness and were more engaged with the robot during the interaction than those assigned to the prevention condition [30]. Despite the relevant work on this topic, no previous study has investigated the impact of regulatory focus on creativity performance in cHRI, the core contribution of our work.

C. Creativity in Child-Robot Interaction

HRI literature recognizes that creative processes between children and robots are rich and can provide important insights into human creativity [7]. However, the type of activity or task being conducted with robots can influence the creative process. For instance, a recent study [5] showed that participating in an activity to program a robot had a higher positive impact on children's creativity skills than participating in one to design a robot or participating in a music activity. In a different setting, children participated in three one-to-one creativity-collaborative tasks with a JIBO robot to address verbal, figural and constructional creativity [4], [6], [31]. The authors aimed to investigate the effects of the robot's creative behavior on children's creativity skills. Children who collaborated on the tasks with a creative robot generated more ideas, were more flexible, elaborated on their ideas more strongly, and showed more originality than those who collaborated on the tasks with a non-creative robot.

Previous research in cHRI also explored ways to promote children's creativity using a storytelling context. Storytelling, one of the oldest and most common activities to develop children's verbal and social skills [32], has always been a popular activity to entertain youngsters. YOLO [33] is a social robot designed for children to use as a character when creating their stories. In a study conducted with the YOLO robot [7], it was found that children who used the robot that expressed social behaviors exhibited higher creativity in their stories than children who used an idle version of the robot. Further, researchers designed a collaborative storytelling activity where a Furhat robot and a child told a story together [8]. Children who engaged in the activity with the robot exhibiting creative behavior did *not* show higher creativity than those who engaged with the robot exhibiting non-creative behavior. The researchers interpreted the results by the frustration that the children exhibited at the robot's interference with their own stories. In this paper, we extend previous research by investigating RFT for verbal creativity for the first time in cHRI, using storytelling as our context.

III. Methods

We conducted a between-subjects design study with two experimental conditions for the two regulatory focus paradigms. We followed a 2X2 mixed experimental design with *priming* (promotion vs. prevention) as a between-subject factor and *storytelling activity* (pre- vs. post-test) as a within-subject factor.

A. Robot System and Scenario Design

We developed a collaborative storytelling game between children and a social robot. It consisted of two storytelling sessions that were pre- and post- a priming interaction to test the experimental conditions (promotion vs. prevention), see Figure 2. A trained operator remotely controlled the verbal and non-verbal behaviors of the robot according to the methodology in [34]. In the priming, the operator followed a strict protocol to induce RFT emotional states in children. In the storytelling sessions, the operator generated the robots' verbal behaviors according to the children's storytelling behavior.

We used EMYS as the robotic agent. It is a robotic metallic head able to express emotions through facial expressions [35]. We employed text-to-speech to reproduce the robot's verbal behavior by using the adult male voice developed by Ivona[1]. The graphical interface was implemented using the Unity Game Engine[2].

1) Priming and Conditions: We created two versions of the priming activity for which the robot's behaviors and graphical interface were designed according to the corresponding experimental condition. We implemented verbal and non-verbal behaviors to suggest happiness and excitement in the *promotion* condition and fear and anxiety in the *prevention* condition. For non-verbal behaviors, we manipulated the robot's facial expression to exhibit emotions. The emotions displayed by the EMYS robot had been validated in a previous user study [35]. Thus, we used the pre-defined EMYS joy and fear expressions for promotion and prevention, respectively. The

[1] Voice used in the current study: https://harposoftware.com/en/12-all-voices

[2] Engine used for the graphical interface in this study: https://unity.com/

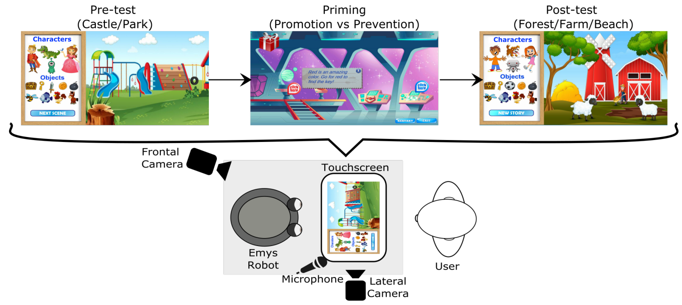


Fig. 2: (Top) Flow schematics of the interactive storytelling activity. (Bottom) Experiment setup.

robot's verbal behavior consisted of different utterances that conveyed messages that also represented the regulatory focus emotions (see Table I). In this part of the activity, children were asked to imagine themselves locked with the robot in a spaceship on planet Mars. Children collaborated with the robot to find a key to get out of the spaceship. In the *promotion* condition, children played a reward-seeking game: they were promised a gift as soon as they managed to get out of the spaceship. In the *prevention* condition, the activity focused on risk-avoidance: children and the robot needed to find the key to escape from the spaceship before an explosion. We were interested in evoking emotions people experience when goals are reached; we ensured that children always found the key and got out of the spaceship. The gift received in the *promotion* condition was a party on planet Mars with the aliens, where the robot danced and asked the child to dance along with it. In the *prevention* condition, children just landed on planet Mars. This ending matched the main assumptions of the promotion and prevention regulatory focus.

2) Storytelling Activity: The storytelling activity took place twice during the study: before and after the priming activity (i.e., pre-and post-test). This activity was developed to assess whether the priming affected children's creativity levels of narrative creation. During the activity, children were asked to create and tell a story to the robot. To help children elaborate on the story, we designed a graphical interface with two versions of the storytelling activity. Each version included four main characters and nine objects that children could move around the scene. We also made available different topics with three different scenes each. To avoid repetitions or story recall, in the pre-test scenario, children chose from two topics (park and castle) and four main characters (princess, prince, crocodile, and alien); in the post-test scenario, they chose from three different topics (forest, beach, and farm) and four different main characters (boy, girl, dog, and robot).

The behavior of the robot for the pre- and post-test scenarios was implemented through the verbal channel only. We designed different kinds of verbal utterances for the robot to provide guidance and support during the game (see Table III). We used the same set of robot verbal behaviors for the pre- and post-test scenarios. The robot's behavior changed only during priming (see Table I). We included back-up stories to

TABLE I: Example of the robot's verbal behaviors in the promotion and prevention conditions, according to the priming stage.

Condition	Stage	Robot's utterances
Promotion	Beginning	*"I am so excited to do this!"*
	Middle	*"I cannot wait to open the gift!"*
	End	*"I am so happy!"*
Prevention	Beginning	*"I am so scared of the explosion!"*
	Middle	*'This is getting scary"*
	End	*"I feel so much better now!"*

prompt children to tell the story in case they were too shy to initiate the interaction or did not know how to tell the story. For the backup stories, we used a modified version of the scripts developed by [36].

B. Research Questions and Hypotheses

The aim of this research was to investigate the effects of RFT on children's creative processes. We posited the following research questions (RQs):

> **RQ.1** *How does a promotion and a prevention regulatory focus affect children's creativity when creating a story with a robot?*

To answer this question, we evaluated children's verbal creativity (dependent variable) before and after a priming intervention with a robot that exhibited the two different motivational strategies specified by RFT (independent variable). Since positive emotions are known to lead to higher creativity [9], we hypothesized that *children in the promotion condition would perform better in verbal creativity than those in the prevention one* **(H.1)**.

We also aimed to investigate the type of verbal behaviors from the robot that were most effective at stimulating children's verbal creativity during story creation.

> **RQ.2** *How does the robot's verbal behaviors influence children's ideas during story creation?*

To answer this question, we followed a descriptive and qualitative evaluation of the interaction between the child and the robot during the storytelling activity. According to the literature, feelings of confidence can stimulate creativity [37], [38], so we hypothesized that *when the robot shows encouragement or asks questions to children, their creativity levels would increase* **(H.2)**. In addition, we took an exploratory use-case study approach, looking into details of how robot behaviors influenced children's creativity when telling a story.

C. Participants

A total of 69 children ranging in age from 7 to 9 years ($M = 7.58, SD = 0.58$) took part in the study. An equal number of participants were assigned randomly to each of the two conditions. We excluded data from 8 participants for various reasons, such as stopping the activity prematurely or speaking to the robot in a language other than English. After exclusion, we gathered data from 32 children (17 girls, 15 boys) in the promotion condition, and 29 children (14 girls, 15 boys) in the prevention condition. We used this data to analyze the results.

We recruited English-speaking children from second and third grades at two private international schools. A consent form was sent to legal guardians, and only children whose informed consent was returned and signed participated in the experiment for data collection. We also asked for children's verbal assent to participate at the moment of interaction. Both the children and their legal guardians were informed that they could stop the activity at any time without giving an explanation. The study was approved by the local institution's Ethical Committee.

D. Procedure

We conducted the study for two weeks in a private classroom at the children's schools with two researchers present. One researcher brought participants to the room, guided the respective child through the activity, delivered the questionnaires post-intervention, and debriefed the child; the second researcher teleoperated and controlled the robot for all the participants. Though the second researcher was in their line of sight, the children were not informed that the robot was teleoperated. During the interaction, the child was seated on a chair at one side of a table, and the robot was mounted on the other side of the table in front of the child. We situated a touchscreen on the table between the child and the robot to display the corresponding activity's interface (see Figure 2). The study consisted of four parts:

1) *Pre-test* — Children were asked to tell a story to the robot using the elements displayed on the interface and/or by introducing new elements of their imagination.
2) *Priming* — Children engaged in the interactive collaborative activity with the robot on either the promotion or the prevention condition. The robot uses verbal and non-verbal behaviors.
3) *Post-test* — Children created a second story and told it to the robot.
4) *Questionnaires and debriefing* — Children filled out a questionnaire with demographic data and then were debriefed.

Since children did not have a time limit in which to tell their stories to the robot, the total duration of the study ranged between $20 - 40$ minutes per child.

E. Measures

To address our research questions, we needed to evaluate the children's verbal creative process pre- and post- the experimental condition. Hence, we designed two schemes to code the verbal behavior of the children and those of the robot during the storytelling activities. See Section VI for details in the supplementary material.

1) Children's Verbal Creative Process: The creative process started when the child introduced the first story idea during story creation and continued until he or she finished their stories. We measured verbal creativity in terms of fluency, flexibility, elaboration, and originality [17], [21], [22].

TABLE II: Coding scheme for measuring children's verbal behaviors when telling a story to the robot.

Creativity Variable	Definition
Fluency	Total number of story elements expressed verbally by the participant during storytelling.
Flexibility	Ideas that fall into different types of categories (i.e., story elements) related to the story plot. These ideas correspond to the total number of characters, actions, scenarios, objects, and affective expressions.
Elaboration	The length of the story considering the time of the first and last story element, which corresponds to the total time children were speaking.
Originality	The level of originality of the ideas during storytelling on a three-point scale: 1 = low, 2 = medium, and 3 = high.

Therefore, we assessed children's creative process by defining four dependent variables, as shown in Table II.

2) Robot's Verbal Behavior: To model the emergence of creativity, we assessed the impact of the robot's behaviors on the level of originality of the children's stories. We measured whether originality level increased, decreased or remained constant after the behavior of the robot had emerged. We counted changes within only a 5 second time window after the robot's verbal intervention. We coded the robot's verbal behavior using the coding scheme defined by [39], [40], as depicted in Table III.

IV. Analysis and Results

A. Inter-rater Agreement

We performed behavioral coding analysis to assess our measures. We used the ELAN[3] software, developed by the Max Planck Institute for Psycho-linguistics [41], to annotate our data according to our coding schemes. We used the recorded audio file for each child to code the data and the lateral video file whenever an audio file was corrupted or unavailable. Overall, all behaviors were coded in approximately 87 hours (an average of 1.5 hours per file).

In line with standard practice [42], a secondary coder double-coded 25% of the data that was selected randomly. We then assessed agreement between both coders to confirm the viability of the coding scheme. We used the EasyDIAg [43] toolbox developed for the calculation of inter-rater agreement measures. The toolbox enables the annotation of time, duration and category for each behavior. We were interested primarily in the categorization of occurring behaviors, thus, we excluded duration matching from our agreement calculation. The Cohen Kappa values -the statistical measure deemed the most significant for the evaluation of agreement in behavioral research [44]- ranged between 0.75 and 0.96 (M = 0.89), denoting high agreement between the two coders. Given the high agreement and the long duration of the files, the remaining data was divided equally and randomly between two primary coders, who completed the analysis individually.

[3]ELAN Software https://archive.mpi.nl/tla/elan

TABLE III: Coding scheme for the robot's verbal behaviors.

Category	Definition
Suggest	Offer for consideration. The robot suggests some ideas for the story. These mainly relate to the category of robot behavior called "back-up stories."
Question	Expression of inquiry that invites a reply, e.g., *"What do you think will happen now?"*.
Declare and Explain	State something and establish reasoning. The robot provides guidance and explains technical moves, e.g., *"Now move your character"* or *"Let's move on."*
Express	Abstract vocalizations that signal empathy and understanding, e.g., *"Ohhh"* or *"Noooo."*
Value	Show encouragement, support, and value, e.g., *"Wow, you are very good at this!"* or *"That's a good idea!"*

B. Manipulation Check

As previous work shows, a promotion-focused paradigm associated with positive emotions (i.e. happiness) stimulated higher creativity in humans than a prevention-focused one associated with negative emotions (i.e. fear) [9], [11]. Therefore, before assessing the impact of our RFT intervention on creativity skills, we validated whether our intervention succeeded in inducing the regulatory focus-related emotions in children by performing a manipulation check.

Given the challenging nature of fear detection from facial expressions, we performed the manipulation check by solely confirming the higher prevalence of happiness facial expressions in the promotion than in the prevention condition. While additional measures, such as wearable sensors (i.e. for fear detection), could be used to perform the manipulation check, we did not include them to avoid arousing feelings of discomfort or uneasiness in the children.

We analyzed children's facial expressions from frontal videos using the Affectiva[4] software. Affectiva uses deep learning algorithms for facial expression analysis; it detects 7 emotions, 15 expressions and extra behavioral measures (including attention and engagement). For our research, we assessed only smile and joy expressions as a measure of happiness. A Wilcoxon signed-rank non-parametric test revealed that children in the promotion condition exhibited a significantly higher number of smiles (W = 199, p = 0.013, M = 9.45, SD = 12.92) and joyful expressions (W = 216, p = 0.03, M = 7.52, SD = 12.04) than those in the prevention condition, which suggests that our intervention worked as expected. These results are retrieved from the analysis and procedures that we conducted for emotional detection from the same study in [30].

Hence, we concluded that RFT was successfully implemented in our interaction. We therefore proceeded to analyze the effects of regulatory focus on children's verbal creativity.

C. Effect of RFT Design on Children's Creativity

To explore the effects of regulatory focus on children's creativity **(RQ.1)**, we analyzed our data according to the creativity measures shown in Table II: fluency, flexibility, elaboration and

[4]Affectiva Software: https://www.affectiva.com/

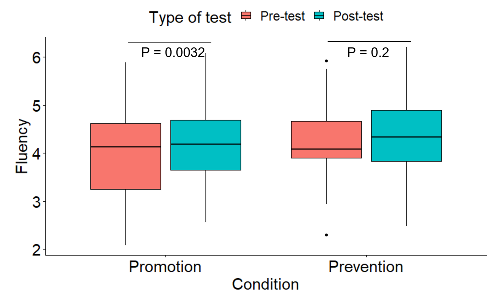
originality. For all our variables, our sample was not normally distributed. As proposed by standard practice, we applied a log transformation to normalize the data [45]. Then, we administered a mixed ANOVA parametric test for each of our response variables with "condition (promotion vs. prevention)" as our *between-subject* variable and "type of test (pre- vs. post-test)" as our *within-subject* variable. Whenever we found a significant effect of any of our independent variables on the dependent variable, we investigated the results further. Our post hoc analysis consisted of a pair-wise paired t-test -using the Bonferroni correction to adjust the p-value- to explore the effects of the within subject factor (type of test) on the response variable in the different conditions (promotion vs. prevention). We describe our results below.

1) Fluency: Our mixed ANOVA analysis yielded a significant effect of the type of test (pre- vs. post-test) on the corresponding fluency dependent variable ($p = 0.016$, $\eta^2 = 0.011$). Our post hoc analysis results show that children exhibited higher fluency of ideas in the post-test than in the pre-test in the promotion condition ($p.adj = 0.032$, $d = 0.341$). We did not observe a similar effect in the prevention condition, as shown in Figure 3(a).

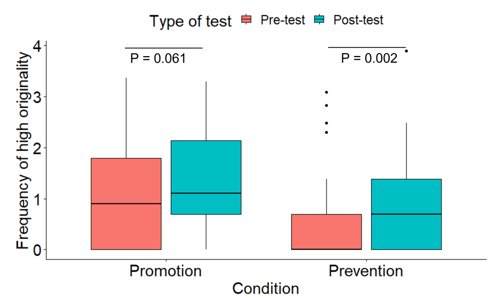
2) Flexibility: As Table II shows, we assessed flexibility as the frequency of the children using ideas belonging to different categories. We therefore investigated flexibility by assessing 5 variables: frequency of ideas related to the characters, actions, scenario, objects, and affective expressions. The ANOVA test results revealed a significant effect of the type of test (pre- vs. post-test) on both frequency of characters and frequency of actions ($p = 0.003$, $\eta^2 = 0.015$ and $p = 0.002$, $\eta^2 = 0.023$, respectively). Furthermore, our post hoc analysis emphasized that both the frequency of characters and frequency of actions were significantly higher in the post-test than in the pre-test in both the promotion ($padj = 0.027$, $d = 0.413$ and $padj = 0.044$, , $d = 0.433$ respectively) and prevention conditions ($padj = 0.041$ and $padj = 0.018$, respectively).

3) Originality: We evaluated originality by associating an originality level (low, medium, high) per story idea. The mixed ANOVA test results showed a significant effect of the type of test (pre- vs. post-test) on the average originality per test ($p = 0.039$, $\eta^2 = 0.017$) and the frequency of the ideas with a high level of originality ($p = 0.033$, $\eta^2 = 0.014$). The administered t-test showed that in the promotion condition, the average originality was significantly higher in the post-test than in the pre-test ($padj = 0.041$, $d = 0.289$). As shown in Figure 3(b), the post hoc analysis also showed that in the prevention condition, the frequency of originality at the high level was significantly higher in the post-test than in the pre-test ($padj = 0.002$, $d = 0.454$). Moreover, the analysis did not show any significant effect of the independent variables on the elaboration-dependent variable.

To conclude, the results suggest that high levels of fluency, flexibility and originality were present in both prevention and promotion conditions in the post-test, which means that priming had an effect on the children's creativity skills. More interestingly, it is in the promotion condition that fluency and average originality were higher in the post-test than in the pre-test. One exceptional result is the higher number of high originality ideas in the post-test compared to the pre-test of the prevention condition.



(a)



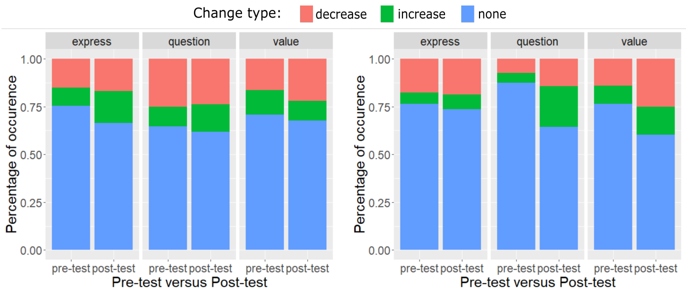
(b)

Fig. 3: The graphs represent normalised values. (Top) The fluency of ideas was higher in the post-test than in the pre-test in the promotion condition ($p.adj = 0.032$). (Bottom) The frequency of ideas with high originality was higher in the post-test than in the pre-test in the prevention condition ($padj = 0.002$).

D. Effect of Robot's Verbal Behavior on Children's Creativity

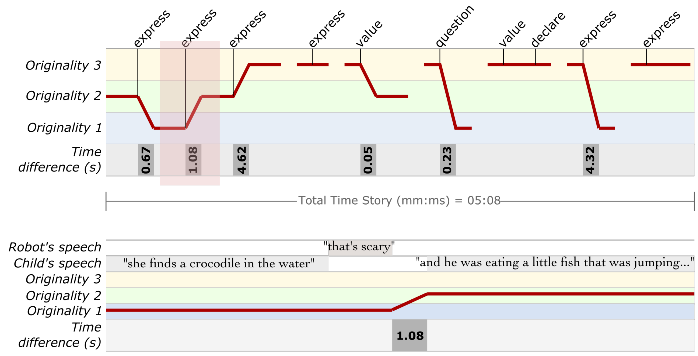
To understand the impact of the robot's behaviors on children's creativity (**RQ.2**), we used two methods. First, we analyzed all emerging robot behaviors during story creation for each participant. We examined the effects of each robot's verbal behavior category (Table II) on the change in originality of children's ideas. Specifically, we analyzed whether originality levels increased, decreased, or remained constant. Second, we randomly selected a case-study to gain a deeper understanding of the creative process dynamics in terms of originality. Changes in originality were tracked within 5 seconds from the occurrence of the robot's verbal behavior. Due to the nature of our study, we implemented descriptive statistics to assess our **RQ.2**, which we describe below.

1) Effect of Robot's Verbal Behaviors on Children's Originality: Figure 4 shows the percentage of changes in the level of originality during story creation as a response to the robot's verbal behavior. Figures 4(a) and 4(b) show changes in the promotion and prevention conditions (pre-vs post-test), respectively. We analyzed only three categories of the robot's behaviors. We excluded *declare and explain* and

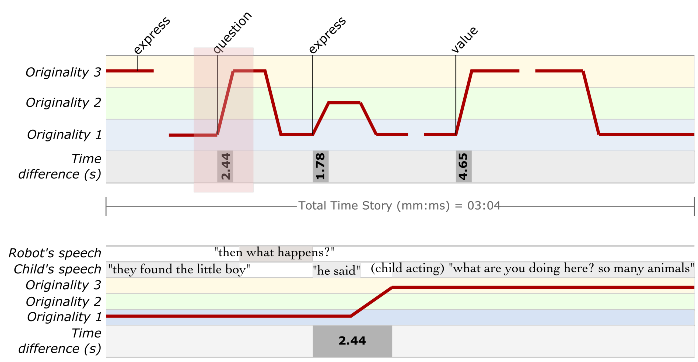


(a) Promotion (b) Prevention

Fig. 4: Originality changes in children's ideas as a response to the robot's verbal behavior.



(a) **Schematic of the dynamics of originality for the pre-test story (top) and for a segment when originality changes (bottom). Four of the robot behaviors decreased originality, two increased it, and four had no impact.**



(b) **Schematic of the dynamics of originality for the post-test story (top) and for a segment when originality changes (bottom). Three of the robot behaviors increased originality, and one did not affect it.**

Fig. 5: Visualization of the case study in the prevention condition. The red line represents the level of originality. *(The graphs illustrate only robot behaviors.)*

suggest due to their low number of occurrences during the storytelling activity. Overall, we observed the trend that the robot's behaviors did not change the level of originality in pre- and post-test interventions. No change in originality was observed as a response to an average of 63.14% of each of the robot's behaviors in both promotion and prevention conditions and both pre- and post-tests. The descriptive analysis also suggests that the robot's verbal behaviors tended to slightly decrease originality rather than increase it. In these cases, the average decrease was 18.3% of the robot's corresponding verbal behaviors as opposed to an increase of an average of 10.5% of the same behaviors. Our results indicate one exception, in the prevention condition: in the post-test, the percentage of *question* behaviors that increased originality was higher than the percentage that decreased it (21.4% vs. 14.2%).

2) Individual Case Study: The exploratory case study sought to capture the temporal dynamics of the originality of story content. We analyzed changes in originality due to the robot's behavior in one participant allocated to the prevention condition. We selected the case of study based on the length of the story and the number of fluctuations in originality. Figure 5 shows the temporal changes in the level of originality after the categorized behavior. Figure 5(a) shows the changes in the pre-test, and Figure 5(b) depicts the changes in the post-test. In this specific case, the story in the pre-test was longer than the story in the post-test. Since the robot's behaviors were dependent on the context of the child's narrative, the number of robot utterances differed among stories.

Overall, the verbal intervention of the robot during the pre- and post-test evoked a change in originality. We observed that the robot's verbal behavior positively impacted the level of originality of the child's ideas more often in the post-test than in the pre-test. A closer examination was done by looking at two segments of the interaction between the child and the robot (area highlighted in red and zoomed in at the bottom of Figures 5(a) and 5(b)). In these examples, the utterances *"that's scary"* and *"then what happens?"* increased the level of originality from level 1 to levels 2 and 3.

V. Discussion and Conclusion

A. Effect of RFT Design on Children's Creativity (RQ.1)

Aligned with previous research [24], children in the promotion condition exhibited higher creativity in terms of fluency of ideas and average originality in the post-test compared to the pre-test, an effect that we did not notice in the prevention condition. Previous work has suggested that inducing happiness by applying a promotion-focused motivational paradigm results in higher creativity in adults [9], [24]. In our work, we confirmed that the same effect applies to children in a cHRI context in terms of both fluency and originality of ideas.

Regarding flexibility, children expressed a higher frequency of ideas related to the categories of characters and actions in the post-test than in the pre-test independent of the priming condition (promotion vs. prevention). This suggests the high potential of engaging in a collaborative activity with a robot to stimulate children's creativity (in terms of flexibility).

Elaboration of ideas was the only creativity measure that was not affected by the RFT design. The stories the children created were freely timed, and therefore they chose when to end their stories. As per Table II, elaboration was calculated as the total duration of the child's story. In many cases, the total duration entailed considerable periods of silence. By comparing the results of elaboration with the results we achieved using the fluency measure that showed that children in the promotion condition generated more ideas in the post-test than in the pre-test; we conclude that children were more silent in the pre-test than in the post-test.

Curiously, although the average originality was higher in the pre- than in the post-test for the promotion condition, the frequency of the highest originality was significantly higher in the post- relative to the pre-test in the prevention condition. This result is consistent with previous research by Alves-Oliveira et al. [7], where children generated more ideas in the enhanced condition (in which the robot used creativity techniques and social behaviors) than in the simple condition (in which the robot used creativity techniques solely). Nevertheless, children's ideas were more original in the simple condition than in the enhanced one.

Based on our findings, we conclude that our first hypothesis **H.1** was solely supported for both fluency and average originality as creativity measures.

B. Effect of Robot's Behaviours on Originality (RQ.2)

Our second hypothesis **H.2** was not supported by our findings in Section IV-D. Results showed a tendency for no change in originality as an effect of most of the robot's verbal behaviors. This suggests that the robot's verbal behavior might not have influenced children's creativity, and, therefore, the creative process was an effect of the regulatory focus design. Nevertheless, by inspecting our qualitative analysis, we observed some cases where the robot's behaviors emerged in the highest level of originality, and this level remained constant (see Figure 5(a)). A constant highest level of originality suggests that the robot fulfilled its role as a storytelling companion, supporting children's story creation.

Nonetheless, when a change in originality happened, our results indicated that the robot's intervention tended to decrease originality rather than increase it. We argue that children perceived the behavior of the robot as an interruption in their line of thought, leading to frustration or distraction. A similar phenomenon was observed in [8], [46], suggesting that children prefer listener robot companions. Further, looking at the different categories of robot behaviors, results indicate that questions and value were detrimental to originality. One reason could be that the questions and the robot's verbal encouragement were too general and did not contribute to story content; recent studies have noted that personalised robot's behaviors can be beneficial for creativity [6] and engagement [47].

The only instance in which the robot's behavior led to an increase in originality rather than a decrease was in the post-test of the prevention condition as a response the robot's questions. This effect is justified by the frequency of the highest originality, which was higher in the post-test than in the pre-test in the prevention condition (Section V-A).

C. Limitations and Future Work

While our study was conducted in the field, it comes with limitations that we now address. First, despite having induced regulatory focus-related emotions in children through priming (promotion or prevention), we did not assess children's natural regulatory focus state, i.e., their natural tendency to regulate towards promotion or prevention. Therefore, a baseline measure of regulatory focus would have been beneficial to better describe our sample. In line with this, future work should also account for regulatory fit between children and the robot.

A second limitation that relates to the first one, is that for some of our results, we lacked a baseline condition for comparison. For instance, our results suggested a better creativity performance (in terms of flexibility) from the children in the post-test than in the pre-test independent of the priming condition (promotion vs. prevention). In the future, we may administer a control condition to investigate whether playing a collaborative game will yield different results if children played it with a human versus with the robot; or with a robot displaying neutral emotions versus a robot showing RFT related emotions.

A third limitation concerns how the data was coded. The originality of children's ideas was coded as a discrete variable in a 3-point scale (from low to high originality). However, additional ways to measure originality could show important results (e.g., the time length of original ideas).

D. Conclusion

This work presented a new approach to stimulate children's verbal creativity using robots. We developed an interactive storytelling activity with a social robot based on regulatory focus motivational strategies (promotion and prevention). We tested our design in an educational environment for the first time in cHRI. Overall, our results show that *a promotion focus interaction with a social robot fosters children's creativity in terms of fluency and average originality of children's ideas*. Nevertheless, our qualitative analysis showed that the effects of the robot's verbal behavior on children's originality of ideas were minimal in this context; further research could help us better understand this finding. Our findings are significant to the HRI and cHRI communities since they provide new directions and guidelines to develop robot behaviors that can benefit children's creative processes in educational applications.

VI. Open Access

The materials of this work, including the detailed coding schemes and data sets for statistical analysis, were stored in the Open Science Framework (OSF) and can be accessed using the following link: https://osf.io/7nq3e/?view_only=15b0da483966481f9bd25ac17a07d43c

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REFERENCES

[1] T. d. C. Nakano and S. M. Wechsler, "Creativity and innovation: Skills for the 21st century," *Estudos de Psicologia (Campinas)*, vol. 35, pp. 237–246, 2018.

[2] E. van Laar, A. J. van Deursen, J. A. van Dijk, and J. de Haan, "Determinants of 21st-century skills and 21st-century digital skills for workers: A systematic literature review," *Sage Open*, vol. 10, no. 1, p. 2158244019900176, 2020.

[3] M. A. Runco, *Creativity: Theories and themes: Research, development, and practice*. Elsevier, 2014.

[4] S. Ali, N. Devasia, H. W. Park, and C. Breazeal, "Social robots as creativity eliciting agents," *Frontiers in Robotics and AI*, p. 275.

[5] P. Alves-Oliveira, P. Arriaga, S. I. Nogueira, and A. Paiva, "Robotics-based interventions for children's creativity," in *Creativity and Cognition*, 2021, pp. 1–8.

[6] S. Ali, H. W. Park, and C. Breazeal, "A social robot's influence on children's figural creativity during gameplay," *International Journal of Child-Computer Interaction*, vol. 28, p. 100234, 2021.

[7] P. Alves-Oliveira, P. Arriaga, M. A. Cronin, and A. Paiva, "Creativity encounters between children and robots," in *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, 2020, pp. 379–388.

[8] M. Elgarf, G. Skantze, and C. Peters, "Once upon a story: Can a creative storyteller robot stimulate creativity in children?" in *Proceedings of the 21th ACM International Conference on Intelligent Virtual Agents*, 2021, pp. 60–67.

[9] M. Baas, C. K. De Dreu, and B. A. Nijstad, "A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus?" *Psychological bulletin*, vol. 134, no. 6, p. 779, 2008.

[10] A. Abele-Brehm, "Positive and negative mood influences on creativity: Evidence for asymmetrical effects." *Polish Psychological Bulletin*, 1992.

[11] E. T. Higgins, J. Shah, and R. Friedman, "Emotional responses to goal attainment: strength of regulatory focus as moderator." *Journal of personality and social psychology*, vol. 72, no. 3, p. 515, 1997.

[12] E. T. Higgins *et al.*, "Promotion and prevention: Regulatory focus as a motivational principle," *Advances in experimental social psychology*, vol. 30, pp. 1–46, 1998.

[13] M. Baas, C. K. De Dreu, and B. A. Nijstad, "When prevention promotes creativity: the role of mood, regulatory focus, and regulatory closure." *Journal of personality and social psychology*, vol. 100, no. 5, p. 794, 2011.

[14] R. E. Mayer, "Fifty years of creativity research," *Handbook of creativity*, pp. 449–460, 1999.

[15] C. W. Taylor, "Various approaches to and definitions of creativity." *R.J. Sternberg (Ed.), The nature of creativity: Contemporary psychological perspectives*, pp. 99–121, 1988.

[16] P. Alves-Oliveira, P. Arriaga, C. Xavier, G. Hoffman, and A. Paiva, "Creativity landscapes: Systematic review spanning 70 years of creativity interventions for children," *The Journal of Creative Behavior*, 2021.

[17] J. P. Guilford, "The nature of human intelligence." 1967.

[18] M. A. Cronin and J. Loewenstein, *The craft of creativity*. Stanford University Press, 2020.

[19] J. P. Guilford, "Creative abilities in the arts." *Psychological review*, vol. 64, no. 2, p. 110, 1957.

[20] R. K. Sawyer, "The interdisciplinary study of creativity in performance," *Creativity Research Journal*, vol. 11, no. 1, pp. 11–19, 1998.

[21] R. J. Sternberg, "Creativity or creativities?" *International Journal of Human-Computer Studies*, vol. 63, no. 4-5, pp. 370–382, 2005.

[22] E. P. Torrance, *Torrance tests of creative thinking: Norms-technical manual*. Personnel Press, 1966.

[23] E. T. Higgins, "Beyond pleasure and pain." *American psychologist*, vol. 52, no. 12, p. 1280, 1997.

[24] R. S. Friedman and J. Förster, "Effects of motivational cues on perceptual asymmetry: Implications for creativity and analytical problem solving." *Journal of personality and social psychology*, vol. 88, no. 2, p. 263, 2005.

[25] E. T. Higgins, "Value from regulatory fit," *Current directions in psychological science*, vol. 14, no. 4, pp. 209–213, 2005.

[26] R. Agrigoroaie, S.-D. Ciocirlan, and A. Tapus, "In the wild hri scenario: influence of regulatory focus theory," *Frontiers in Robotics and AI*, vol. 7, 2020.

[27] A. Cruz-Maya and A. Tapus, "Adapting robot behavior using regulatory focus theory, user physiological state and task-performance information," in *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. New York, USA: IEEE, 2018, pp. 644–651.

[28] A. Cruz-Maya, R. Agrigoroaie, and A. Tapus, "Improving user's performance by motivation: Matching robot interaction strategy with user's regulatory state," in *International Conference on Social Robotics*. Springer, 2017, pp. 464–473.

[29] N. Calvo-Barajas, M. Elgarf, G. Perugia, A. Paiva, C. E. Peters, and G. Castellano, "Hurry up, we need to find the key! how regulatory focus design affects children's trust in a social robot," *Frontiers in Robotics and AI*, vol. 8, p. 197, 2021.

[30] M. Elgarf, N. Calvo-Barajas, A. Paiva, G. Castellano, and C. Peters, "Reward seeking or loss aversion? impact of regulatory focus theory on emotional induction in children and their behavior towards a social robot," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 2021, pp. 1–11.

[31] S. Ali, T. Moroso, and C. Breazeal, "Can children learn creativity from a social robot?" in *Proceedings of the 2019 on Creativity and Cognition*, 2019, pp. 359–368.

[32] A. Wright, *Storytelling with children*. Oxford University, 1995.

[33] P. Alves-Oliveira, S. Gomes, A. Chandak, P. Arriaga, G. Hoffman, and A. Paiva, "Software architecture for yolo, a creativity-stimulating robot," *SoftwareX*, vol. 11, p. 100461, 2020.

[34] L. D. Riek, "Wizard of oz studies in hri: A systematic review and new reporting guidelines," *J. Hum.-Robot Interact.*, vol. 1, no. 1, p. 119–136, Jul. 2012.

[35] J. Kedzierski, R. Muszyński, C. Zoll, A. Oleksy, and M. Frontkiewicz, "Emys—emotive head of a social robot," *International Journal of Social Robotics*, vol. 5, no. 2, pp. 237–249, 2013.

[36] J. M. Kory-Westlund and C. Breazeal, "A long-term study of young children's rapport, social emulation, and language learning with a peer-like robot playmate in preschool," *Frontiers in Robotics and AI*, vol. 6, p. 81, 2019. [Online]. Available: https://www.frontiersin.org/article/10.3389/frobt.2019.00081

[37] R. A. Beghetto and J. C. Kaufman, *Nurturing creativity in the classroom*. Cambridge University Press, 2010.

[38] J. M. Froiland, "Parents' weekly descriptions of autonomy supportive communication: Promoting children's motivation to learn and positive emotions," *Journal of Child and Family Studies*, vol. 24, no. 1, pp. 117–126, 2015.

[39] J. S. Gero and T. Mc Neill, "An approach to the analysis of design protocols," *Design studies*, vol. 19, no. 1, pp. 21–61, 1998.

[40] Y. Jin and O. Benami, "Creative patterns and stimulation in conceptual design," *Ai Edam*, vol. 24, no. 2, pp. 191–209, 2010.

[41] P. Wittenburg, H. Brugman, A. Russel, A. Klassmann, and H. Sloetjes, "Elan: a professional framework for multimodality research," in *5th International Conference on Language Resources and Evaluation (LREC 2006)*, 2006, pp. 1556–1559.

[42] J. M. Chorney, C. M. McMurtry, C. T. Chambers, and R. Bakeman, "Developing and modifying behavioral coding schemes in pediatric psychology: a practical guide," *Journal of pediatric psychology*, vol. 40, no. 1, pp. 154–164, 2015.

[43] H. Holle and R. Rein, "Easydiag: A tool for easy determination of interrater agreement," *Behavior research methods*, vol. 47, no. 3, pp. 837–847, 2015.

[44] R. Bakeman and V. Quera, *Sequential analysis and observational methods for the behavioral sciences*. Cambridge University Press, 2011.

[45] M.-L. T. Lee, *Analysis of microarray gene expression data*. Springer Science & Business Media, 2007.

[46] Y. Tamura, M. Kimoto, M. Shiomi, T. Iio, K. Shimohara, and N. Hagita, "Effects of a listener robot with children in storytelling," in *Proceedings of the 5th International Conference on Human Agent Interaction*, ser. HAI '17. New York, NY, USA: Association for Computing Machinery, 2017, p. 35–43. [Online]. Available: https://doi.org/10.1145/3125739.3125750

[47] M. E. Ligthart, M. A. Neerincx, and K. V. Hindriks, "Design patterns for an interactive storytelling robot to support children's engagement and agency," in *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, ser. HRI '20. New York, NY, USA: Association for Computing Machinery, 2020, p. 409–418. [Online]. Available: https://doi.org/10.1145/3319502.3374826