Can Children Emulate a Robotic Non-Player Character's Figural Creativity?

Safinah Ali
MIT Media Lab
Cambridge, USA
safinah@media.mit.edu

Hae Won Park
MIT Media Lab
Cambridge, USA
haewon@media.mit.edu

Cynthia Breazeal
MIT Media Lab
Cambridge, USA
cynthiab@media.mit.edu

ABSTRACT

Can intelligent non-player game characters (NPCs) increase children's creativity during collaborative gameplay? Children's creativity is influenced by collaborative play with creative peers through social emulation. In this paper, we study children's emulation of an AI-enabled social NPC as a new type of game mechanism to elicit creative expression. We developed Magic Draw, a collaborative drawing game designed to foster children's *figural* creativity that allows us to investigate the efficacy of an NPC's *creativity demonstration* in enhancing children's creativity in the resulting drawings. The NPC is an emotively expressive social robot that plays Magic Draw with a child as a peer-like playmate. We present the results of a study in which participants co-draw figures with a social robot that demonstrates different levels of *figural* creativity, to understand whether an NPC's creativity in its own contributions stimulates *figural* creativity in children. 78 participants (ages 5–10) were randomly assigned to a non-creative robot control condition (C-) and a creative robot condition (C+). Participants who interacted with the creative robot generated significantly more creative drawings, and hence exhibited higher levels of *figural* creativity. We infer that the social robotic peers' demonstration of *figural* creativity in a collaborative drawing game is emulated by young children. We discuss a new game design principle grounded in the social learning mechanism of emulation, specifically, that social and intelligent NPCs in games should demonstrate creative behavior to foster the same in human players.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative interaction**; *HCI design and evaluation methods*; • **Applied computing** → **Psychology**; • **Computer systems organization** → **Robotic autonomy**.

KEYWORDS

Creativity Support Tools; Co-creativity; Child-robot Interaction; Non-Player Character; Social Emulation.

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1 INTRODUCTION

Creativity is defined by the ability to fluently produce novel ideas that add value. Creativity in children has been shown to facilitate problem solving, adaptability, self-expression and improve health [49]. Integrating creative skills into educational institutions' curricula provides increased learning benefits [41]. Creativity also has social, cultural and economic benefits since most inventions today are a result of creative applications of existing knowledge and technology to new problems [31, 39]. Integrating creative skills into educational institutions' curricula is, therefore, a must to support many aspects of children's learning [41]. Unfortunately, research shows that as children progress from kindergarten to elementary school (ages 8-10), their creativity drops due to convergent and structured school curricula as measured by standardized creativity tests such as the Torrance Test of Creative Thinking (TTCT) [47, 50, 53]. Another study found that children's creativity has been declining over time, which they referred to as the "creativity crisis". Between 1984 and 2008, children's average Elaboration score (taking an idea and elaborating on it in a novel way) on the TTCT, for every age group from kindergarten through 12th grade, fell by more than one standard deviation [33]. Researchers believed that this phenomena is a result of continuous evaluation, convergent curricula and deprivation of free time to play and explore. Fostering creative thinking in children is especially important in this era of Artificial Intelligence where repetitive and mechanistic jobs shift from humans to computers.

It is not surprising that several studies in Human-Computer Interaction (HCI) have attempted to foster creativity in children, by introducing various digital aids called Creativity Support Tools (CST) [14, 15, 44] in the classroom. The evolution of HCI research has sparked a new area of creativity research that focuses on collaboration, which includes CSTs that aid collaboration in use with other people as well as collaborating with a software, tool or program [15]. While these tools often introduce playful and exploratory media for children to express creativity, they lack the social aspects of creativity that can be fostered by interacting with a social embodied agent. More recent works have explored how children learn creativity while collaborating with socially interactive AI agents as CSTs [1, 2, 30].

Socially interactive AI agents (such as social robots) have been used as effective pedagogical agents for young children and have been shown to contribute to both cognitive and affective gains [6, 34]. Their ability to personalize learning, enhance engagement through expressive interactions, and participate in collaborative learning activities as a peer situate social robots as an interesting learning intervention [9, 37]. Among pedagogical agents, social robots have the unique ability to interact with children in a social-emotional way because of their ability to perceive and express emotion through a physical embodiment. Therefore, it is not surprising that social robots have been used as a psychological study tool, such as studying children's emulation of growth mindset and curiosity while interacting with a social peer [19, 38].

From the literature of creativity and cognition, we know that creativity can be learned and is influenced by a person's environment and social interactions [41]. Creative problem solving in classrooms is often scaffolded by extrinsic factors, such as social interactions with peers and teachers, the nature of collaboration, and the nature of the task itself [29, 43]. Creativity can also be fostered by the classroom activities, e.g., often when they are presented in permissive and game-like fashion [53]. Of these external factors influencing creativity, one of the most significant is **collaboration**, where multiple people work together towards a common goal [12]. Furthermore, playful interactions and games are a proven medium for effective concept learning as well as for fostering creativity [43].

Given how playful interactions and social interactions with others influence children's creativity, especially in collaborative tasks, we explored whether interacting with social robots in a collaborative game can promote creative expression in children. More specifically, we explore wether children emulate a social robot's creativity expression in the game. Non-Player Characters (NPCs) are computer controlled characters which the players can interact with, often seen as virtual or social agents, and guided by Artificial Intelligence (AI) techniques, acting in a predetermined way or executing a specific set of game-related functions. We designed a collaborative drawing game, where a physical robot takes the role of an NPC that demonstrates *figural* creativity in the game. We discuss what we can deduce about designing games aimed at fostering creativity based on what we learned about creativity emulation of robotic NPCs by the human player. In this work, we developed a social agent that can deliver creative and collaborative interactions while playing an artistic drawing game in which the child and the robot can demonstrate their creativity. Through a randomized controlled trial, where we compare children's expressed creativity while they interact with a creative robot with a non-creative robot, we demonstrate how children emulate the robotic NPCs creativity levels and express high creativity. Lastly, we provide design recommendations for games for fostering creativity using social robotic NPCs in collaborative gameplay.

2 RELATED WORK

2.1 Creativity

There are several frameworks for defining creativity, and what qualifies as creative behavior. Guilford defines creativity as the embodiment of thought in the form of external behavior, consisting of three characteristics: fluency, flexibility, and originality [23]. Modern researchers describe creativity as the process of generating artifacts or ideas, that are novel to the person, to the person's environment or to the world, that generate surprise, and that add value to the system [7, 31]. Creativity is often viewed in conjunction with divergent thinking, which is the potential for original thoughts [41]. Creativity is expressed in different forms depending on the nature of the task and the medium of creative expression - *figural* creativity (e.g., drawing, painting, sculpting) and *verbal* creativity (writing, storytelling, composition, discourse) [22]. In this work, we focus on *figural* creativity that is illustrated through a drawing game.

Even though creativity is challenging to measure empirically, researchers have developed creativity assessment tasks with coding systems that conceptualize and measure different forms of creativity through questionnaires [32, 35, 51, 54] and task-based assessments [10, 29, 46]. We used the Torrance Test of Creative Thinking (TTCT) [50] for assessing children's baseline creativity prior to the study. We used the Test for Creative Thinking - Drawing Production (TCT-DP) [52] to score *figural* creativity from the drawings generated during the child-robot collaborative drawing game.

2.1.1 Creativity and Social Interaction. Children's creativity in classrooms is greatly influenced by external factors including their social interactions with others – such as collaboration, question asking and reflection [23, 28]. Collaborative environments are especially beneficial for fostering creativity [43]. Children's motivation and personality interact with the environment and components of the creative process to enhance the development of creativity in themselves [10]. Children are wired to learn with and from friendly others and socially emulate the behaviors and attitudes of others [57]. Other creators in children's environment include teachers and peers who also act as potential role-models for creativity [4, 41, 56]. Creativity is also promoted when activities are presented in permissive and game-like fashion [53].

2.1.2 Creativity and Games. The benefits of play-based learning approaches, and how they foster children's creativity, have long been understood [36, 44]. Games have the power to afford behaviors that constitute creativity, such as generating multiple ideas to solve a problem, generating novel ideas that add value to a solution, metacognition, asking questions, and cross-contextual thinking. Digital games, especially those categorized under the genre of Sandbox games such as Minecraft [45] often provide opportunities for generating new artifacts, allowing for creative expression. From diverse theoretical perspectives it is accepted that play is the first creative activity of the child and that imagination originates and develops in play. Creative play in its different forms is of great importance in development because it stimulates curiosity, flexibility, and improvisation and promotes problem-solving behavior that leads to learning, imitation, and adaptation to change. Research that has analyzed the contributions of play to child development has stressed the crucial role of play in human development. Many studies carried out within different epistemological frameworks have confirmed that play stimulates creativity [16, 25, 42], identifying play as a predictor of divergent thinking. In the kindergarten approach to learning, Resnick [40] emphasizes the significance and centrality of play in creative learning, and how it has a positive influence on both children's motivation to learn as well as their learning gains. Isen et al. [27] demonstrated how positive affect facilitates creative problem solving, and games have been shown to induce positive affect in children.

In our work, we utilize the knowledge of these two stimulants of creativity, 1. interaction with and social emulation from peers, and 2. playful interactions, to design a collaborative drawing game where children interact with a social robotic NPC that exhibits creativity. The robot contributes as a peer-playmate in the drawing game while exhibiting *figural* creativity by generating novel artifacts (drawings) and talking about its own creative process.

2.2 Emulation of Social Agents

A majority of creativity-oriented research efforts in HCI have focused on developing novel digital-interactive aids like Creativity Support Tools (CSTs), especially in the form of Graphical User Interfaces, as opposed to studying social interaction with computers [44]. Some tools support collaboration with other individuals, such as IdeaVis, which is a hybrid workspace and interactive visualization for collaborative sketching [17], as well as with the software/algorithm, such as Drawing Apprentice, which is a system that collaborates with the artist in real-time drawing [11]. Although less frequently, social interactions with virtual agents have been used to stimulate creativity before. Shneiderman et al. embedded a software agent into an architectural design tool [13]. However, non-embodied interactive agents lack the social expression abilities that embodied social agents possess. Previous work has demonstrated that children socially learn from others including emulating the skills and attitudes expressed by peer-like social robots. Social robots have previously been used as pedagogical agents in the context of educational games to foster positive learning behaviors, such as curiosity, grit, and emotive engagement [6]. Several studies have looked at how children socially emulate a robot's learning behaviors, such as *verbal* creativity, empathy, curiosity or growth-mindset. Gordon et al. demonstrated how children can socially emulate more pro-curious attitudes from a "curious" robot, and exhibit greater curiosity related behaviors such as free-exploration and question-asking (compared to children who play with a non-curious robot) [8, 19]. Park et al. demonstrated that a robot exhibiting a growth-mindset can help foster a growth-mindset in young children as well as enhanced perseverance through challenge when solving difficult puzzles [38]. Ali et al. demonstrated how children can emulate *verbal* creativity from a social robot that can articulate creative descriptions of ambiguous line drawings [1]. This establishes social emulation as an important mechanism of social learning that children seem to employ with peer-like social robots. Building on this, we explore if a robot that demonstrates *figural* creativity can help foster *figural* creativity as a learning behavior in young children.

2.3 Social Robots and Creativity

The use of robots in the classroom to foster creativity in children is not new. Lego Mindstorms, Bots Alive, Cozmo, Pop bots, Yolo [2, 5, 20, 55] are examples of robot construction kits aimed to teach children about robotics and allow for creative expression. These works, however, use the robot as a toolkit that children use to create, rather than as an agent that children interact with. Jung et al. demonstrated how having a reflective conversation with an embodied artifact in the making positively influenced the learning process [28]. Kahn et al. demonstrated that a robot's verbal and non-verbal behaviors such as question asking, positive reinforcement, challenging, and positive affect can help adults be engaged in a creative activity for longer times and come up with more creative ideas [30].

Ali et al. [1] demonstrated how children model a social robot's *verbal* creativity during a verbal gameplay interaction. Participants played the Droodle creativity game with a social robot that involved generating humorous creative titles for abstract figures. Participants that interacted with the creative robot (one that exhibited more fluent ideas that are more novel and creative based on a standardized scoring scheme) also generated significantly more fluent ideas and scored higher on novelty and creativity, as compared to participants that interacted with the non-creative robot. This demonstrated how children can emulate a social robot's artificial *verbal* creativity. Our work similarly explores whether children can emulate a social robot's artificial *figural* creativity.

Social embodied agents have also been used as NPCs in games, where researchers demonstrated how the assertiveness of the robotic NPC influences the player's emotions. Several learning interactions with social robots have utilized the robot as a game playing peer. Social robots have been used as a role-switching robot to enhance children's learning during a vocabulary learning game [9], as competitive peer in a vocabulary learning game [48], and as a collaborative peer in a *verbal* creativity game [1]. Given that social robots are increasingly being used in education and have been shown to be effective learning tutors and playing companions [6, 34, 37], this work aims to investigate the efficacy of peer-to-peer interactions with robots as an NPC in a collaborative *figural* creativity game.

In a previous study, Alves-Oliveria et al. [3] studied the role of a robot, in comparison with a tablet, in stimulating creativity in humans in a collaborative drawing game. The social robot, controlled remotely in a Wizard of Oz manner, acted as a collaborative peer in a drawing activity, taking turns with the human, to complete their drawing. They found no significant effect of the robot's presence on children's expressed *figural* creativity. In contrast, we have developed a fully autonomous child-robot interaction and drawing model. While their study aimed to understand the role of *embodiment* on children's *figural* creativity, we instead look at *creativity demonstration* by the social robot as a stimulant for children's *figural* creativity. Our goal is to explore the mechanism of social emulation of a peer-like robot's creative drawing behaviors by young children.

3 SYSTEM DESIGN

3.1 Non-Player Character Platform

The non-player character (NPC) platform in this work is a social agent, Jibo. It is an 11-inches tall table-top robot that is socially expressive. It has a three-axis cylindrical body with a touch-screen face, touch sensors on its head, two cameras to support face detection, text-to-speech with speaker output, and automatic speech recognition with speaker input [26]. We make use of Jibo developer tool-kit to communicate with an Android tablet as a shared drawing surface. The game app's logic lives on the Android application, which communicates with Jibo over WiFi. We made the choice of using the Jibo robot since we wanted to build a completely autonomous collaborative robotic interaction, which was enabled by Jibo's ability to sense audio and receive commands from the tablet's interactions enabled. Further, we wanted to make use of Jibo's library of expressive body animations to express curiosity, joy and pride during the interactions. The Jibo robot was a commercialized platform and has been tested to be appealing to children and child-friendly to use. Even though Jibo does not have hands to draw, the robot conveys intent and agency while it "draws" on the tablet – looking down at the screen, moving its body as it draws, while talking as it "draws". The experimenters also discussed with children that Jibo uses WiFi to connect to the tablet without physical hands. This made for a believable experience, and we verified that participants perceived the robot as doing the drawing while we asked post-test questions about Jibo's ability to draw.

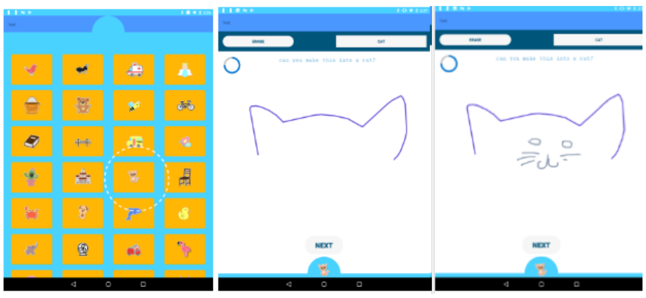

Figure 1: Collaborative Gameplay. Left to right: The child selects a target category from a list of categories *(cat)*. The child draws a starting prompt (cat ears). The robot converts the starting prompt into a *cat*.

3.2 Magic Draw: A Collaborative Drawing Game

In our interaction scenario, Jibo takes the role of a fully autonomous playmate who plays a drawing game with a child using a touch screen tablet. The objective of the game is for the child and robot to come up with a shared drawing. The tablet interface affords drawing using a finger, and makes it convenient to capture drawings' stroke data.

As discussed in Related Work, we use the Test for Creative Thinking - Drawing Production (TCT-DP) as inspiration for designing the gameplay. The main difference is that in the test, examinees start from a fixed prompt and convert the drawing into anything. In our game, we turn this into collaborative drawing game-play where one player selects a drawing objective and draws an initial stroke followed by the second player drawing more strokes to convert it into the selected objective. We designed this interaction dynamic to make it fun, collaborative and engaging for young children, and for both players to have agency over the drawing. As aforementioned, collaborative gameplay is is known to strongly influence and motivate creative thinking.

The robot and the child take turns, building up on each other's drawing contributions, to complete the final figure. To begin, one player starts by drawing any initial stroke on the tablet and prompting the other player to convert the doodle into a meaningful object (such as a cat) (Figure 4). The drawing goal is selected by the player from 55 preset model categories. The game is played for three rounds, four minutes each (two minutes per player) before the game terminates (Figure 2). The time of each round is kept the same to control for time of interaction, and the time limit was decided after play-testing the game with children and observing engagement. This collaborative drawing game supports various aspects of creative thinking. First, players are encouraged to demonstrate divergent thinking, attempting to imagine how to build upon a starting stroke to complete a figure. It also supports fluency of thought, involving what Guilford terms as ideational fluency (i.e., the ability to rapidly produce ideas in succession). The game also supports associational fluency (i.e., the ability to generate artifacts to associate the starting prompts to the target object). The game mechanic also allows players to change the target object for the same prompt, or change the prompt for the same target object. This requires the other player to demonstrate flexibility of thought, that is come up with many different categories of ideas to solve the problem. The creative challenge of the game lies in being able to imagine an object from an abstract starting prompt.

3.3 Generative Drawing Model

For the robot to support a co-drawing interaction, we developed an autonomous way to generate doodles that can incorporate the child's contributions. During the robot's turn, we trained a model that can generate drawings starting from the child's strokes to the final target doodle. Our learning algorithm is based on Recurrent Neural Network (RNN) that is trained on human drawn images of 55 common everyday objects. We made use of Sketch-RNN, developed by Ha et al. [24], to train a model on quick human-drawn doodles representing 55 classes from the QuickDraw Dataset [18] to generate new doodles for each class. Each class of QuickDraw is a dataset of 70K training samples, in addition to 2.5K validation samples and 2.5K test samples. These 55 categories were chosen by a literacy expert based on age appropriateness for children in the 5–10 year age group. The model is a Sequence-to-Sequence Variational Autoencoder (VAE), which takes a vector sketch as an input and outputs a latent vector. To predict endings of incomplete strokes, we used a method developed by Ha et al. where they use the decoder RNN as a standalone model to generate a sketch that is conditioned on previous points. The decoder RNN first decodes an incomplete sketch into a hidden state **h**. Afterwards, it generates the remaining points of the sketch using **h** as the hidden state. These completed sketches can also be controlled in terms of their randomness by using the temperature variable τ. Since we used generative modelling techniques, the number of drawings that can be generated and recognized by the model are not limited, and hence every new drawing that the robot creates from the child's stroke is unique, making the task more open-ended.

The Sketch-RNN model runs on a local server in the vicinity of the tablet. The tablet sends and receives messages from the server which includes sending the starting prompt image and the category selected, and receiving the generated stroke image (Figure 3). There is no perceived latency in the tablet communicating with the drawing model. The RNN generates new drawings around the starting prompt as soon as the child lifts their finger from the tablet after the first stroke and sends it back to the tablet in real time. The drawing is generated as an animation of strokes, similar to actual real-time drawing. The tablet also sends the selected category to the robot, and the robot responds with the category name, for instance, "Oh a cat." In order to ensure that the user's perceived interaction was smooth, the robot speech and animation is synced with the drawing model's starting time, which immediately follows the child losing touch contact with the tablet. The robot's behaviors (e.g., looking down at the tablet and verbally responding to the target category selected) provides the impression that the robot is directly engaged in the drawing process.

Figure 2: Turn-taking interaction of the collaborative drawing game. Left: The robot is completing the drawing prompt started by the child on the tablet interface. Right: A child is completing the drawing prompt started by the robot.

3.4 Robot Behavior

The robot NPC is designed to be a fully autonomous "artistic" peer that collaboratively makes drawings with the child. While the drawings are generated on the tablet screen, the robot logs information about which doodles are being drawn and when. The robot looks down upon the screen during its turn to draw and verbalizes accompanying utterances. For instance, the robot says, *"OK, a cat. I think I can make that drawing into a cat."*, *"Here I go!"*, or *"Watch me convert your doodle into a cat."* The robot also verbally engages the child by asking for feedback, *"What do you think about my drawing?"*, or *"Do you think that looks like a cat?"*. These text prompts are picked from a pre-defined library of utterances that involve questions, reflection and intent. Additionally, the robot also displays the selected category icon on its screen face to demonstrate an association with the category chosen.

4 INTERACTION DESIGN

4.1 Introduction

Children are first introduced to the robot by the experimenter as a playmate that they will be playing the Magic Draw game with. During this period, Jibo ice breaks with the child by introducing the gameplay before the main rounds begin.

EXPERIMENT: Hi [participant]. My name is [experimenter] and I am a researcher studying games and robots. This is Jibo. Jibo is a social robot that loves to play games. Today, you will be playing a drawing game with Jibo. Do you want to play?

CHILD: *Response*

EXPERIMENT: Awesome. Remember that you can stop playing at any time you want. Let's meet Jibo who will tell you all about the game.

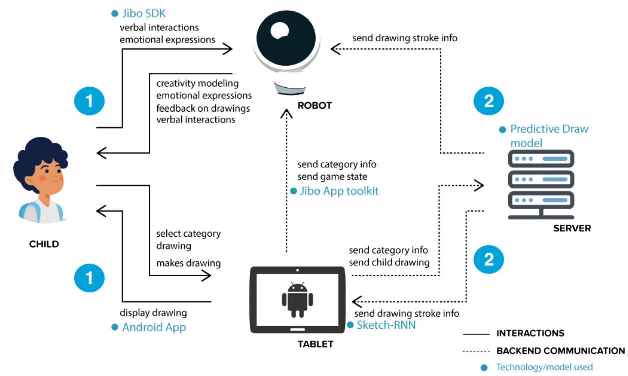

Figure 3: System components. 1. Children interact with the robot and the tablet verbally and for making drawings. 2. The robot and the tablet communicate with the server to send category information and receive drawing stroke information.

The robot then engages in a short introduction to build rapport and introduce the game.

ROBOT: Hi, my name is Jibo. I am a social robot. What is your name?

CHILD: Chasity

ROBOT: [*excitedly*] Hi Chasity! Welcome to the Magic Draw Game. We will be making some drawings together. Are you ready to begin?

CHILD: Yes

ROBOT: [*looking down at the tablet*] I will show you how to play the game. First, select a category from the menu below.

A menu drawer pops up. The child can then open the menu and select one of the categories, for example, *cat*.

ROBOT: Oh, a cat! Now draw any shape on the screen.

Afterwards, the child initiates the round by drawing a starting prompt using one stroke. The robot indicates beginning to draw as soon as the child lifts their finger from the tablet.

ROBOT: Alright! Now watch me turn it to a cat.

Then for the remainder of the round which is set to 2 minutes, the robot attempts at generating as many cat drawings as possible based on the child's starting prompt. The robot also tried to improvise upon its existing drawings by erasing and redrawing them.

ROBOT: I will try another way to draw a cat.

Within the time limit, the child can also provide a new starting prompt for the robot, which would replace the original starting prompt, and the robot continues drawing with the new prompt. The child can also switch categories with a new prompt. When the time is up, the players switch roles.

ROBOT: I'm going to choose the elephant! I am drawing a starting shape on the screen. Can you convert to an elephant? You can draw as many different elephants as you'd like. Remember to press the DONE button after each drawing.

The child starts drawing as many elephants as she can for 2 minutes. During these two tutorial rounds, the robot NPC walks through the gameplay with the child, requiring no experimenter intervention.

4.2 Gameplay Rounds

After the tutorial, the child and the robot play six more rounds in total. Each round begins with the child or the robot selecting a category and providing the starting prompt. Then the other partner completes the drawing and creates as many drawings as possible in the two minutes.

Every time the child completes one drawing, i.e., presses the **Done** button, a screenshot of the drawing is taken with a sound and animation feedback. After the child completes each drawing, the robot provides feedback. The robot matches the drawing to the model category, and based on the confidence of image classification, it responds with a positive or neutral remark. If the drawing has an 80% or higher match to the category, the robot responds with a positive feedback. Positive responses include, "Good job!", "That was a good one!", "You are an artist!", and "That looks so much like an ant". These utterances are accompanied by expressive animations of *joy, excitement* or *happiness.* If the model has a match confidence of less than 80% with the category, the robot responds with a neutral feedback. Neutral responses include, "Oh that was an ant!", "Let's try another one", or "Do you want to try making another doodle?", and are accompanied by animations of *interest, confusion,* or *curiosity.* We deliberately chose not to include any negative feedback to avoid hindering creativity.

4.3 Gameplay End

Both players play three rounds each, and then the robot ends the game and bids farewell. The game also has a timer displayed on the top left that indicate the amount of time left before the turn switches. The entire gameplay lasts about 15 to 20 minutes including the gap in turn switching and selecting categories.

5 STUDY DESIGN

To investigate whether a robot's own creative behavior can positively influence children's creative expression, we designed a between-subjects randomized controlled trial study.

5.1 Participants

78 participants of the 5–10 year-old age group were recruited for the study (34 female, 44 male). The average age of the participants was 7.53 (S.D. = 1.93). The subjects were recruited as a part of the Somerville after-school activities program at the public schools in Somerville, MA. All participants and their guardians signed an informed ascent and consent form to participate in the study and to permit us to collect demographic, assessment, audio and video data. The recruitment materials, study protocol, and data collection protocol were reviewed and approved by the Institute Research Board at Massachusetts Institute of Technology. Three participants did not complete the interaction, and the results for 8 participants were not recorded accurately due to a network problem. Hence, data from 67 participants was used for the final analyses.

5.2 Pretest

All 78 participants were administered the Torrance Test of Creative Thinking (TTCT) as a part of the pretest activity. The TTCT is a paper-based evaluation that consists of 2 sets of assessment activities: a *verbal* creativity test and a *figural* creativity test. The purpose of conducting the TTCT was to drive a quasi-random assignment into groups such that their creativity scores are counter-balanced across the two conditions, described next.

5.3 Study Conditions

Participants were counterbalanced and divided into two study condition groups as shown in Table 1. We performed repeated random clustering until the differences in the participants' pretest creativity scores, age, and gender were minimal across the two groups.

Table 1: 78 Participants participated in the study. Participants were divided into counter-balanced groups based on their TTCT scores, gender and age.

Group	n	TTCT scores	Gender	Age
C-	41	42.91 ±5.16	F=20, M=21	7.09 ±1.96
C+	37	43.33 ±6.30	F=14 M=23	7.89 ±1.91

Creative Robot Condition (C+). : The robot system in this condition produced more creative drawings as defined by the metrics of the TCT-DP figural creativity test: continuations (Cn), completion (Cm), new elements (Ne), connections made with a line (Cl) between one figural fragment or figure or another, connections made to produce a theme (Cth), and speed of drawing (Sp) [52]. During the robot's turn, we adjusted the temperature variable of the drawing model τ to be 0.2 to reduce the randomness in drawing. Since this led to more accurate (less random) and fully connected drawings that fit the category, we hypothesized that they are more continuous, completed, and are connected to the selected theme (Cm, Cl, Cth). Further, we kept the speed of drawing to the default speed (60 fps). The robot always drew true to the selected category. This led to higher quality drawings with a better model match to the category that the child selects. This led to a better connection to the selected theme (Cth). The length and number of interactions were controlled for across the two conditions. We validate this hypothesis of these drawings being rated as more creative in the following section.

Non-Creative Robot Condition (C-). : In the non-creative robot condition, the robot system was configured to produce less creative drawings as measured by the TCT-DP figural test parameters. We adjusted the temperature parameter τ of the generative model to be the 0.8 to increase the randomness of the drawing – thereby producing lower quality drawings with a lower model match to the category that the child selects. Further, we adjusted the frame rate of rendering to 30 frames per second to generate the drawings more slowly. We also made the model periodically select an incorrect category to make the drawing not match the selected theme.

5.3.1 Validation of Study Conditions. To validate that the drawings generated in the C+ condition were scored as more creative per the

Figure 4: Adjusting the drawing's creativity by adjusting τ. Left: Highly creative drawing of *(cat)*. Non-creative drawing of *cat*. Drawing has lower continuation, connectivity and connection to the theme.

metrics of the TCT-DP test, we analyzed the drawings produced during the robot's turn. Specifically, we compared the TCT-DP scores of 12 robot drawings generated by the creative model and 15 robot drawings by the non-creative model. An unpaired t-test revealed that the model type had a significant effect *(p<0.01**)* on the drawing's creativity scores (Table 2) as we intended. Hence, we validated that the manipulations of the model's temperature, the accuracy of the drawings, and adjusting drawing speed indeed led to an appropriate change in the drawing's creativity as intended per conditions.

Table 2: Drawings generated by the C+ model were significantly more creative than the C- as measured by TCT-DP

Model condition	n	TCT-DP score
Non-creative Model (C-)	15	20.33 ±7.86
Creative Model (C+)	12	28.91 ±6.69
p		p=0.0064**

5.4 Hypothesis

Our main hypothesis is that children who play the collaborative drawing game with the creative robot (C+) will exhibit higher levels of *figural* creativity in their own drawings than children who play with the non-creative robot (C-).

5.5 Post-test

In order to understand children's perceptions of the robot's creativity and peer-like influence during the interactions, we administered a post-test questionnaire consisting of 5-point likert scale and yes/no questions:

- Q1 : Do you think that Jibo helped you finish the drawings? (yes/no)
- Q2 : Do you think that what Jibo said was helpful for your drawings? (yes/no)
- Q3 : Do you think that Jibo is a better artist than you? (yes/no)
- Q4 : On a scale of 1 to 5, how good of an artist do you think Jibo is? (5 being highest, 1 being lowest)

Note that we used the term *artist* in the post-test questionnaire instead of *creative*, since it was an easier term for young children to understand.

5.6 Data Collection and Measures

5.6.1 Data Collection. We used the following sensor setup or logging method to collect gameplay data:

- Tablet action logs:
  - All drawings drawn by the child in three rounds.
  - All drawings drawn by the robot in three rounds.
  - Time taken for each drawing.
- Overhead GoPro camera:
  - Video of the interaction (birds-eye view).
  - Audio of the interaction.
  - Researchers conducted and recorded the post-test interview responses of the participants.

5.6.2 Creativity Measures. We adapted the TCT-DP test to analyze the creativity of the drawings. The Magic Draw game is different from the TCT-DP test since it has turned the test into a collaborative interaction with two players and used a tablet to capture children's drawings instead of paper. Hence, it is less open ended than the actual test itself, since one player is deciding the target category of the drawing, but the other player still has freedom to draw it in any way they like. Since there are no available tests for less open-ended drawing tasks, we make use of a modified TCT-DP to measure the drawings' creativity, where we exclude some metrics of TCT-DP that were not relevant to this game. Our resulting creativity measures are outlined below:

- Continuations (Cn): Any use, continuation or extension of the given figural fragments.
- Completion (Cm): Any additions, completions, complements, supplements made to the used, continued or extended figural fragments.
- New elements (Ne): Any new figure, symbol or element.
- Connections made with a line (Cl) between one figural fragment or figure to another.
- Connections made to produce a theme (Cth): Any figure contributing to a compositional theme or "Gestalt".
- Boundary breaking that is fragment dependent (Bfd): Any use, continuation or extension of the "small open square" located outside the square frame.
- Boundary breaking that is fragment independent (Bfi).
- Perspective (Pe): Any breaking away from two dimensionality. *We exclude this parameter since we used a tablet for the drawing task.*
- Humour and affectivity (Hu): Any drawing which elicits a humorous response, shows affection, emotion, or strong expressive power.
- Unconventionality-a (Uc, a): Any manipulation of the material such as paper. *We exclude this parameter since we used a tablet for the drawing task.*
- Unconventionality-b (Uc, b): Any surrealistic, fictional and/or abstract elements or drawings.
- Unconventionality-c (Uc, c): Any usage of symbols or signs.
- Unconventionality-d (Uc, d): Unconventional use of given fragments.

- Speed (Sp): A breakdown of points, beyond a certain score-limit, according to the time spent on the drawing production.

We recruited three objective coders who were blind to the study's hypothesis and the participants' study condition to review and score the drawings generated in the child's turn. We conducted an inter-coder reliability test to validate the reliability of coding and found a high correlation of 0.82. We used these scores for calculating the TCT-DP measures of the drawings.

5.7 Results

We ran Shapiro-Wilk (S-W) normality test and Levene's equal variance test on our data. We failed to reject Shapiro-Wilk's null hypothesis ($p>0.05$) that the data is normally distributed, and Levene's null hypothesis ($p>.05$), hence we conclude that there is insufficient evidence to claim that the variances are not equal. Hence, we conducted unpaired t-test comparing creativity scores of drawings generated by participants in the control condition (C-) and the experimental condition (C+), as measured by the TCT-DP test. The unpaired t-test revealed that participants that interacted with the creative robot (C+) generated drawings that scored significantly higher on *figural* creativity (M = 42.27, S.D = 14.63), than participants that interacted with the non-creative robot (C-) (M = 32.88, S.D = 9.64), $t(65) = 1.99$, $p = .0023$ (Figure 5). The results are shows in Table 3.

Table 3: TCT-DP scores of participants. Unpaired t-test revealed that the study condition had a significant effect on participants' *figural* creativity

Study Groups	n	TCT-DP scores
Non-Creative robot (C-)	34	32.88 ±9.64
Creative robot (C+)	33	42.27 ±14.3
p		$p = .0023^{**}$

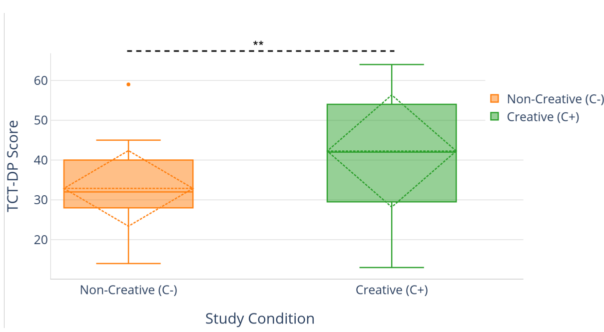

Figure 5: Participants that interacted with the creative robot scored significantly higher on the TCT-DP test compared to the non-creative robot.

Hence, we validated our hypothesis that children emulate the robot's expressed *figural* creativity during a collaborative drawing game.

In the post-test questionnaire, we learned children's insights about the game interaction, and how they perceive the robot as an artist (Figure 6). We also wanted to learn if they could perceive the robot's creativity and whether they thought it helped them. We asked the following questions in the post-test interview:

Q1: Do you think Jibo helped you finish the drawings? (yes/no). More participants in the creative robot condition reported that Jibo was helpful in finishing their drawings than participants in the non-creative robot condition. Participants viewed the more creative peer as the more helpful one.

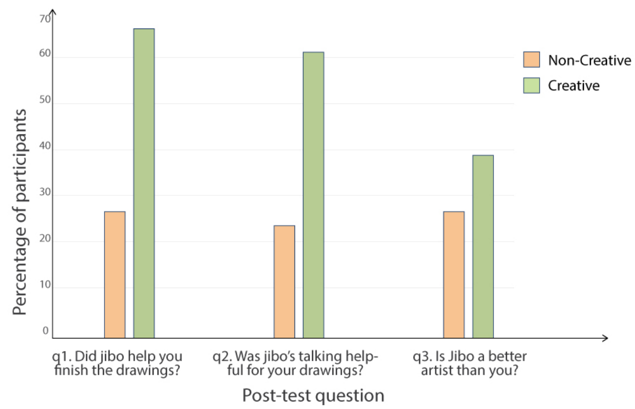

Figure 6: Post-test questionnaire Q1, Q2, Q3 results (yes/no responses). More participants in the creative robot condition responded "yes" and perceived the robot to be more helpful and a better artist.

Q2: Do you think that what Jibo said during the game was helpful for your drawings? (yes/no). More participants in the creative condition thought of the robot's talking to be helpful. One participant in the C+ condition said "Yes, it was helpful to me when I was asking him what to do and he did it right away, he didn't need other reminders to do it, it is really easy to give him what to do or say." Another participant explained "Yes, he said good to my drawings."

Q3: Do you think Jibo is a better artist than you? (yes/no). Participants in the creative robot condition were more likely to confirm that the robot was a better artist (C+ = 39%, C- = 27%). However, a majority of participants in both conditions did not think that the robot was a better artist than they were.

Q4: On a scale of 1 to 5, how good of an artist do you think Jibo is? (5 being highest, 1 being lowest). With unpaired t-test, we found significant difference in how the participants perceived the robot to be an artist, children in C+ condition rating the robot higher than children in the C- condition: C+ (M = 2.97, S.D. = 1.51) and C- (M = 2.24, S.D = 1.12); $t(65) = 1.99$, $p = .03$. (Figure 7). We can conclude that on average, participants were able to successfully perceive the higher quality of drawings of the C+ robot.

6 DISCUSSION

In this study, we demonstrated how artificial *figural* creativity exhibited by a social robotic NPC in a collaborative drawing game enhances the *figural* creativity expressed in children's drawings. Social emulation is the primary social learning mechanism as children

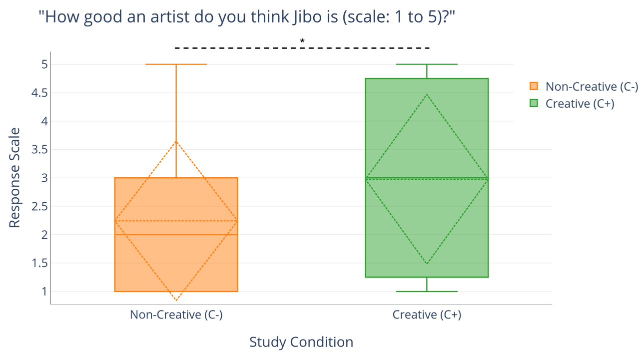

Figure 7: Q4 result. Participants in the creative robot condition perceived the robot to be more creative than participants in the non-creative robot condition *(p=.03*).*

observed the robot peer's drawing contributions during gameplay and listened to the robot's reflections on its own drawing process. Note that the robot did not coach or provide explicit feedback to children on their drawings. We found that this was sufficient to influence children to express greater creativity in their own their drawings as measured by the TCT-DP *figural* creativity. Participants that interacted with the creative robot drew significantly more creative drawings than participants who interacted with the non-creative robot. Participants not only emulated the robot's *figural* creativity, but also perceived the creative robot as a better artist.

A previous study conducted by Alves-Oliveira et al. [3] demonstrated that the presence of a social robot during collaborative drawing did not have a significant effect on participants' creativity as compared to a tablet. The study provided evidence about how embodiment of the collaborative peer alone has no influence on creativity. In our work, we hypothesized that it is not just the embodiment of the collaborative partner, but also the creative expressions exhibited by it when positioned as an NPC in a collaborative game, that can foster *figural* creativity in children. Informed by theories of creativity, we observe that children's creative learning is influenced by their social interactions with a robot playmate that models creative behavior. This finding is consistent with prior work in HRI that reports that children socially emulate robotic peers' learning behaviors such as *verbal* creativity, curiosity and growth mindset [1, 19, 38]. Through our randomized controlled trial, we demonstrated that this also holds for *figural* creativity in a collaborative game. Hence, we validated our hypothesis that children socially emulate the robot's expressed *figural* creativity in a collaborative game to enhance their own creative expression. We observed that, when positioned as an NPC that exhibits creative behaviors, the robot is perceived as highly creative by the participants, which in turn emulate this creativity in their own gameplay behavior. This finding informs design principles for game mechanics and NPCs in collaborative games that aim to elicit creative behaviors in children during gameplay. We suggest that the NPCs in such games themselves exhibit the behaviors the designers aim to elicit in the player, such that the players can perceive and emulate them.

We also demonstrated that our RNN-based generative drawing model adapted from [24] enabled collaborative drawing between the child and the agent. We adjusted parameters of the model to control for the level of creativity of the generated drawing, measured by TCT-DP, which enabled us to conduct a between-subject study. While there was a possible disconnect between Jibo's embodiment and its ability to draw (since it has no hands), the robot's synchronized movement with the drawing, looking down, speech prompts, and children's post-test response to their perception of Jibo as an artist demonstrate that the drawing interaction was believable for the participants.

This work shows how social robots as NPC agents in collaborative games can enhance children's *figural* creativity through demonstrating and expressing creative behaviors. Along with prior studies, we show that having the NPC game agent to demonstrate a desired behavior can in turn help foster that same desired behavior in the human player. Through this work, we inform the mechanical design of games and behavioral design of pedagogical NPC agents that aim to foster creativity in children. The presence of an NPC with social interaction capabilities alone is insufficient to bring out creativity in young children, but when its social interactions and gameplay related behaviors are orchestrated in a way that the target user can implicitly and explicitly perceive their conjoined message, a powerful mechanism of social emulation can be observed.

Our social emulation finding is a valuable design principle for game designers of NPCs that aim to elicit specific behaviors from children during gameplay. While using social agents as player companions, it is essential to have them model the behaviors that we want children to emulate. For *figural* creativity, that implies having the robot generate highly creative artifacts, and through its verbal and non-verbal interactions, reflect on the creative process. Designers will also benefit from designing open-ended games that allow for creative expression such as drawing, and there is no correct way to draw something. It is also crucial that the creative activity, as well as the robotic NPC's behavior is non-assessing since that hinders creativity.

7 CONCLUSION AND FUTURE WORK

In this work, we studied the effects of artificial creativity demonstration of a social robotic NPC on children's *figural* creativity during collaborative gameplay. We presented methods to developing creative expressions for artificial agents- the agent's verbal and nonverbal interactions with children and an RNN-based generative drawing model that can be adjusted for different levels of creativity. We verified our hypothesis that children emulate the creative figural expression demonstrated by an NPC framed as a collaborative playmate. Namely, children who interacted with a robot NPC that generated more creative drawings and talked about them also drew more creative drawings themselves. Given social agents have been shown to be effective pedagogical agents and starting to be used in educational serious game settings, it is imperative to critically think about how these agents' behaviors can influence children's learning behaviors, such as creative thinking. This is especially the case where children's creativity is in decline as they progress through the formal education system.

It is important to note that while social robots are not the only way to provide creativity support through social emulation, they are certainly are a compelling way to do so. These AI-enabled social agents are an affordable way to scale human support (e.g., provided by teachers) to amplify and augment personalized learning. To understand the role that *embodiment* plays in fostering creativity, one could compare children's interaction with other types of agents such as graphical avatars, VR characters, AR characters, voice agents and compare the impact on children's creativity gains. It would also be interesting to see this interaction replicated with different robot platforms to evaluate the role of the robot's form factor in influencing children's creativity (e.g, does it matter if the robot has arms, can physically draw, etc.). While in this work, we study the role of the robot's creative expression in fostering figural creativity, in order to disambiguate between the role of embodiment and social interactions of the robot in creativity stimulation, a 2X2 study can be conducted, where the variables are embodiment (tablet vs robot) and creativity demonstration (creative vs non-creative). In future work, we could also explore how explicit coaching compares to social emulation.

We hope our work provides useful insights to game designers and researchers in developing game mechanics and agents (such as NPCs) intended to foster creativity in children. In prior work, social emulation was leveraged to foster curiosity, growth mindset and verbal creativity. Our work is a compelling value add, since the strategic use of NPCs in this way could be layered on top of many other types of peer-to-peer collaborative games in order to foster a combination of positive learning gains and attitudes. Further work would be needed to explore the design principle of NPC's display of these values to achieve synergistic beneficial outcomes. This also opens important ethical questions as social emulation of NPCs should only be used to benefit children rather than to manipulate them to serve goals that are not in their best interest.

7.1 Limitations

In this work, we were only able to provide a narrow construct of *figural* creativity constrained to 55 categories of drawings of simple objects. *Figural* creativity can allow for much more complex drawings. The model was trained on a doodle data which contains low quality drawings, and hence does not generate very high quality drawings itself. This can be reflected in the post-test questionnaire results, where children in both study conditions did not rate the robot very highly as an artist ($C+ = 2.97 \pm 1.51, C- = 2.24 \pm 1.12$).

Creativity encompasses a much wider array of behaviors that can be explored using other interactions and mediums such as verbal games, music generations, or construction games. Advances in generative machine learning methods have opened up new avenues and forms for artificial artistic expressions. AI agents have the potential to use generative networks to express various forms of creativity through different media such as drawing, construction, poetry, art styles, patterns, and poses [21]. Our work opens up the opportunity to explore how these different forms of artificial creativity can be embedded in agents that children interact with, and help them be more creative in playful, game-like contexts. As a part of our future work, we aim to expand this study to other models of creativity with the support of AI generative models and evaluate whether children can emulate other forms of the social agent's creativity. We would also like to investigate how the effect of a social agent's creative scaffolding in one task transfers to another task without the agent being present, and hence evaluate the long-term effect on children's creative thinking.

Next, we limitedly adapted the traditional paper-based TCT-DP test to a game-like digital implementation. We positioned the robot as an AI-enabled NPC since games are playful environments that allow scaffolded spaces for expression of creativity and collaboration. However, in using a digital UI, there are some parameters of creativity defined by the TCT-DP that the game couldn't support, such as boundary breaking, that is more affordable on paper. There is a need to expand the original TCT-DP metrics to the digital world, especially since the digital space provides so much potential to think outside the box of the physical space. In our future work, we will provide methods for the user to express their creativity in the digital UI, and an expanded test scale to measure *figural* creativity in the digital space.

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