Project Co-Art: Improving Children's Imagination through AI-based Human-Computer Co-creation

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***Abstract*—This research proposes a new AI-based human-computer co-creation system, Co-Art, which helps enhance children's imagination and creativity through drawing. In contrast to existing approaches, we use a more efficient and child-friendly form of voice and brush interaction, where the machine understands the picture described by the child and visualizes it in an abstract style. The machine's artwork can inspire the child to create a second version. In a comparative experiment, we found that the aesthetic and richness of the images that the Co-Art-trained children drew showed a significant difference compared to the control group($p<0.01$), with a significant increase in imagination and creativity($p<0.05$).**

***Index Terms*—Children's imagination, AI collaboration, Drawing, Education**

I. Introduction

The precise meaning of imagination is based on what is known and logic to make scientific associations and generate pioneering ideas. Imagination is a prerequisite for innovation. Imagination runs through the entire process of thinking and judgment, and new ideas originate from imagination. Nature has endowed human beings with a unique ability that is imagination, and it is fundamental to propel our species forward, as well as children's development. Marilyn Fleer stated that imagination could help children pave the way for more easily understanding complex concepts through role-playing. Children can use imaginative thinking to develop a form of scientific consciousness [1]. Creative and imaginative experiences allow children to develop the full range of human potential, improve the capacity for thought, action, and communication, and extend physical and perceptual skills [2]. Imagination can be cultivated and exercised, and cultivating imagination is a core content of the educational process. So it is worth exploring different methods which could stimulate children's imagination. Many previous studies have revealed the positive influence of artistic activities on the development of imagination [3] [4] [5] [6] [2]. Since there are no strict rules, drawing is a simple way for children to expand their imagination. Many existing educational systems apply drawing to stimulate the imagination of children. We compared and analyzed the existing systems by dividing them into feedback and collaboration types according to the interaction method. According to the analysis results, we proposed a drawing education system that can foster children's imagination through AI collaboration.

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II. Background and Related Work

A. Children's Imagination

Imagination has been an essential concept in the history of the western world. Since Kant's Critique of Pure Reason [7], the study of imagination has occupied a high position in his critical philosophical system. Einstein [8] also stated, "Imagination is more important than knowledge because knowledge is limited, whereas imagination encapsulates the world, drives progress, and is the source of the evolution of knowledge." In former research, imagination is often associated with innovation. The emergence and development of new things and technologies are inseparable from innovative human thinking. With the in-depth exploration of basic research, the phenomenon of how imagination arises has gradually been unveiled from a psychological point of view, but it is still a complex process to control imagination and acquire it when needed.

Nevertheless, imagination is not a trait that only a few people can possess. Children have come up with imaginative ideas from their earliest childhood. One of the most critical topics in studying children's educational psychology is the development of creativity and its significance for children's future development [9]. Researchers have found that imaginative skills can be trained through play, creative writing, theatrical creativity, and drawing [10]. Furthermore, in response to the changes and challenges brought about by the exploding development of technology in the 21st century, the educational model known as STEM (Science, Technology, Engineering, Mathematics) was proposed and later added Art [11] to remove the limitations of STEM [12], and takes STEM to the next level. It allows students to link their learning in these key areas with artistic practices and design guidelines to stimulate imagination and creativity.

By narrowing down the scope of the research, our studies draw upon the perspective of children to capture their imagination with drawing.

B. Drawing Education and Imagination Improvement

We divided the existing drawing education systems into two types according to the interaction method.

(1) Type of feedback. With the development of the Internet, online drawing education platforms have emerged. Hualeme is an art education application that provides online live drawing courses for children. In addition to general online courses, Bear Art stimulates children's interest through interactive games. Taking lessons from a teacher is a traditional way of learning, but there could be a substantial right and wrong relationship between the teacher and the student. There are also AI assistant systems that support the drawing process. ShadowDraw [13] is an interactive drawing system that can provide suggestive object contours to users to guide the drawing. iCanDraw [14] helps users to refine the sketches by suggesting lines. The type of feedback is suitable for developing the drawing ability, but there are constraints for children to expand their imagination freely.

(2) Type of collaboration. A study revealed that a social robotic peer could help children think creatively [15]. Cobbie [16] is a robot that can support early-stage ideation. A robot could be a partner, but there is low accessibility. DuetDraw [17] allows users to draw pictures with the AI agent collaboratively. The Drawing Apprentice [18] is also an AI drawing partner that can draw based on the user's input. StoryDrawer [19] provides collaborative drawing between children and AI to support visual storytelling for children. These works revealed the potential of AI as a collaborator in the creation process. This type of collaboration can bring new ideas to children instead of judging the quality of the drawing.

In this research, we adopt the way of AI-based human-computer co-creation. Unlike existing works, we ask children first to have the big picture of what they want to draw so that they will have a big picture in their minds. Since the AI's understanding and presentation of this content may be completely different from the user's imagination, it can stimulate the imagination. Instead of providing a straightforward image at a glance, we offer an abstract painting style, giving children more space for imagination.

C. Artifical Intelligence for Drawing

Generative adversarial networks (GANs) were first proposed by Goodfellow et al. [20] in 2014 and have gradually become popular in computer vision research in recent years. GANs are unsupervised learning models composed of two deep neural networks (acting as generators and discriminators, respectively) that play with each other to achieve realistic data generation. In 2017, Aaron et al. [21] proposed Vector Quantised Variational AutoEncoder (VQ-VAE). Based on this, Ramesh et al. [22] released the DALL-E 1 model in 2021, capable of generating surrealistic and high-quality images based on textual content. In the same year, Esser et al. [23] also improved on VQ-VAE by proposing VQ-GAN, which substantially enhanced the realism of the generated images.

III. System Design

In this section, we describe the human-computer interaction design of Co-Art and present the main applications of the GAN and CLIP algorithms in this system, concluding with the system software design.

A. Design of Interaction and User Experience

Co-Art's core interaction is to push the boundaries of human imagination by creating drawings with machines. It consists of two sub-parts. All interactions are web-based and can be accessed by users on cell phones, tablets, or computers. As shown in Fig 1, the user enters Co-Art's gallery, turns on the microphone permission of the device, and inputs by voice. Voice is a natural communication that aligns with the user's daily human communication habits. In the early stage of interaction with Co-Art, it does not require the user to perform too many behavioral actions, such as typing but expresses ideas in the form of dictation. After the user's voice input is completed, the AI is responsible for understanding the user's language and inputting it to the Co-Art model to transform the text content into a visual image. When interacting with Co-Art, the user's mind may be presented with a pictorial scene or just a text graphic. For example, "*A horse is running happily on the grass.*" The human can construct a picture with this sentence, but the AI's understanding and presentation of this content may differ from human imagination at this time, and this difference is the possibility that can stimulate the imagination. In the second part, on the first part of co-creation after the generation of drawings, we further expand the ability of human-machine cooperation for more diverse interactions. Users can edit existing pictures to recreate them, including choosing a different color, adjusting the brush's thickness, and adding geometric patterns. For example, "*a horse running happily on the grass*." There is already a picture created by the AI based on the user's input. The user could use the brush to draw a circle in the grass area, and after clicking to finish, AI will create a new drawing based on what the user added. In each stage of interaction, users can extend the different possibilities that can come out of the initial content by creating with AI, and this possibility is presented to the user as a visual graphic element, from words to pictures, completing a leap of imagination.

B. Software Design

Users can use the system in two combinations (1) tablet PC + capacitive pen, and (2) graphics tablet + pressure-sensitive pen + computer, thus enabling easy and quick human-computer co-creation of specific drawing themes. Fig 2 shows the process of using Co-Art on the user's tablet PC. The home page shows some of the paintings created by the user and Co-Art before, with the start button in the middle of the page.

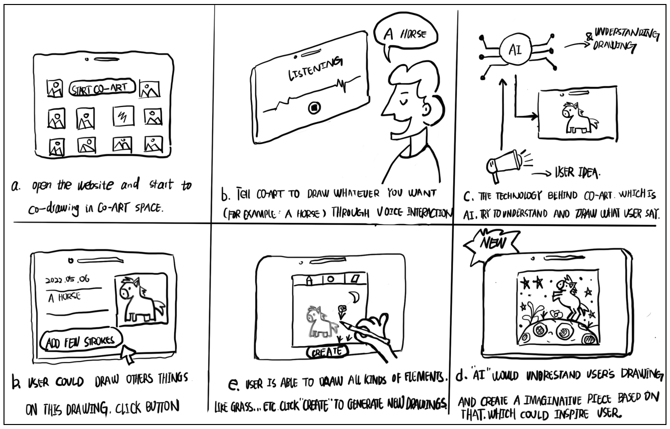

Fig. 1. Interaction Sketch

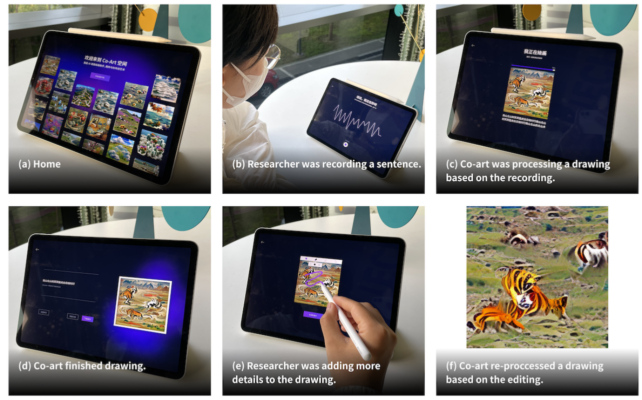

Fig. 2. Design of Interaction

The user records a sentence, and Co-Art will automatically convert it into text, which is simple, efficient, and very friendly for children with a low level of word recognition. Then, the system continuously updates and presents the pictures generated by the AI model according to the drawing theme entered by the user (the model will present the final picture after generating 80-100 intermediate pictures). The AI model can automatically understand the semantic meaning of the drawing theme entered by the user and retrieve the corresponding image, and then generate a unique image that approximates the drawing theme through the AI algorithm. While the AI model generates the intermediate picture, the user can trigger the pause control at any time to create a second picture on the intermediate picture at the moment of pause. The child can add new elements to the intermediate picture or change the existing elements, as shown in the image (e), where the user wipes off a tiger and adds more grass to the intermediate picture. After the changes are made, the user can trigger the corresponding controls to input the human-computer co-created intermediate diagram into the AI model, which will continue to build on this foundation in the direction that best fits the drawing theme until it generates the final diagram that the AI thinks is closest to the drawing theme. The final drawing with the theme of "Tiger chasing Tibetan antelope" was generated in this human-computer co-creation process.

IV. USER STUDY

This section focuses on how we conduct user tests and present the results.

A. Procedure

Twenty subjects were recruited and divided into control and experimental group to conduct the test.

1) Subjects were introduced for the experiment, including privacy strategies.
2) Subjects' imagination was initially assessed via Williams Prefer Measurement Forms [24] and divided equally into control and experimental groups based on scores so that each group had an equivalent level of imagination. A description of the scale is given below and in the Appendix.
3) Introduce the subjects to the system and allow them to try it out for 10 minutes afterward, and help them to solve any problems that may arise during the trial.
4) Give the control group Topic A to draw with pen and paper and the experimental group Topic B to draw with Co-Art.
5) After the experimental group has finished drawing, take a half-hour break and give them Theme A again, using paper and pen.
6) Experts in the field of children's drawing were invited to evaluate the drawings of both groups for Theme A.

B. Measurements

The Williams Prefer Measurement Forms is a psychometric instrument that measures creative tendencies. The test has 50 questions, each followed by three response options: fully, partially, and not at all. There are four dimensions: adventurousness, curiosity, imagination, and challenge. The test results in four scores, which, when added to the total score, result in five scores. The higher the score, the higher the level of creativity. The imagination dimension is used in this paper.

For the control and experimental groups, theme A is, please create a painting about spring. Theme B for the experimental group was: Please choose any of the following keywords to create a sentence and a painting. The keywords were Martian, spaceship, black hole, rabbit, sun god, and monster. The subjects were grouped equally according to their scores on the Williams Prefer Measurement Forms to ensure that the initial imagination levels of the two groups were comparable. The only variable was that the experimental group would perform a human-computer art co-creation using Co-Art. The test concluded with an expert assessment of the paintings of both groups of subjects for Theme A. The evaluation content included three indicators: aesthetics and richness, imagination and creativity, childishness, and innocence [25]. Two experts with more than five years of experience in art education for children were invited.

C. Subjects

Participants came from Beijing, China (N = 20), 60% girls (N = 12), and 40% boys (N = 8), an average age of 12 years. The mean score for Williams Prefer Measurement Forms for the control group is 25, and the mean score for the experimental group is 26. The study followed empirical permission requirements and ethical principles. Fig 3 shows a child is creating with Co-Art.

Fig. 3. A child is creating with Co-Art

V. Results

This section presents the test results for the control and experimental groups, and a one-way ANOVA was conducted. The experiment results suggest that Co-Art has a role in enhancing children's imagination.

Fig 4 shows the work created by the control group for Theme A, Fig 5 shows the work created by the experimental group for Theme A, and Fig 6 shows the work created by the experimental group for Theme B and Co-Art.

Fig. 4. Control Group Works for Theme A

One-way analysis of variance (ANOVA) was used to perform statistical calculations on the scoring results. One-way ANOVA is a statistical method used to test the difference between multiple means by deriving the mean of two samples to determine whether the factors significantly affect the experiment results [26]. When $p<0.05$, the difference between the two groups is significant, and when $p<0.01$, the difference is highly significant.

Fig. 5. Experimental Group Works for Theme A

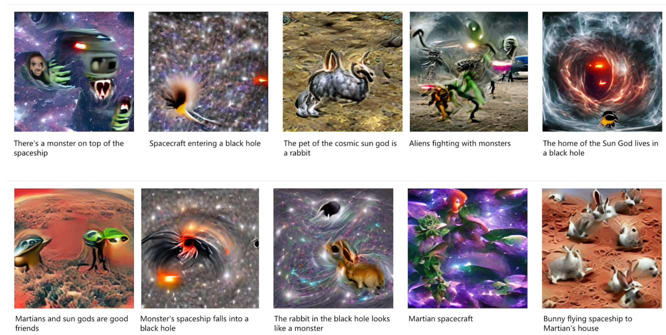

Fig. 6. Experimental Group Works for Theme B Created with Co-Art

Table I shows the results of Expert A's scores. The difference between the control and experimental groups is highly significant in the dimension of aesthetics and richness and imagination, and creativity($p<0.01$). The difference between the two groups was insignificant in the measurement of childishness and innocence($p=0.23$).

TABLE I
Results of Expert A's Scores

Dimension	SS	df	MS	F	P-value	F crit
aesthetics and richness	2.45	1	2.45	10.7560	0.0041	4.4138
imagination and creativity	4.05	1	4.05	8.5764	0.0089	4.4138
childishness and innocence	0.2	1	0.2	0.45	0.5108	4.4138

Table II shows the Expert B's results. In the dimension of aesthetics and richness, the difference between the control and experimental groups is significant ($p<0.05$). In the dimension of imagination and creativity, the difference between the two groups was insignificant($p=0.4239$). The difference between the two groups was negligible in measuring childishness and innocence($p=0.1752$).

TABLE II
Results of Expert B's Scores

Dimension	SS	df	MS	F	P-value	F crit
aesthetics and richness	6.05	1	6.05	6.4437	0.0205	4.4138
imagination and creativity	1	1	0.45	0.6694	0.4239	4.4138
childishness and innocence	1.25	1	1.25	1.9911	0.1752	4.4138

Fig 7 shows the distribution of the two experts' scores for the control and experimental groups, respectively. The distribution of the scores of the experimental group is not lower than that of the control group for both Expert A and Expert B (abbreviated as A and B in Fig 8). In particular, the scores of the experimental group are significantly higher than those of the control group for the indicators "aesthetics and richness" and "imagination and creativity".

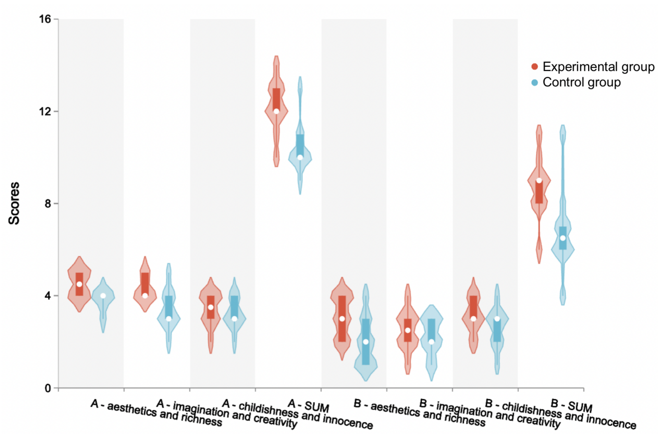

Fig. 7. Experts' Scores about Control&Experimental Group

VI. DISCUSSION

This section focuses on a discussion of the article's findings.

A. Importance of Imagination

The importance of imagination has been widely recognized in children's development. Imagination enables people to deal with uncertainties and solve problems [27]. Imagination naturally degrades as children grow, but it can be trained through artistic activities. We looked at 9 existing educational drawing systems and analyzed them in two categories: the type of feedback and the type of collaboration. As a result, compared with the type of feedback, collaborative types provide children with more free-thinking space and help them develop their imagination. Based on this background, we proposed Co-Art, which allows AI and children to create drawings together. Co-Art expands the broader realm of the child's mind through the difference between images in the child's mind and the AI's representation of the same language. Co-Art allows children to add more elements to the drawing, and the AI will understand the elements and present them to complete the picture together. The abstract style will enable children to think and understand themselves rather than telling them the answer to the drawing. Instead of evaluating children's drawings, Co-Art helps children develop their imagination by combining their ideas with an understanding of artificial intelligence.

B. Analysis of Test Results

The test results are basically in line with the hypothesis of this paper: Co-Art contributes to the development and nurturing of children's imagination. Firstly, in the dimension of aesthetics and richness, the two experts' scores showed a significant difference between the performance of the experimental and control groups, indicating that the children's drawings showed a better sense of beauty and richness after Co-Art training. Secondly, there was no difference in performance between the control and experimental groups in the dimension of childishness and innocence. This is mainly consistent with reality, as childishness and innocence are more related to age and stage of development [28]. Finally, the two experts had different opinions on the dimension of imagination and creativity. One expert believes that the difference between the experimental group's performance and the control group's after the Co-Art training is highly significant, proving that Co-Art helps children improve their imagination and creativity. Another expert, however, had a different opinion and analyzed the scores to show no significant difference in the performance of the two groups. This could be related to the small number of subjects.

C. Main Findings of Co-Art

Co-Art relies on VQGAN as the technical support of the system to make the AI understand humans better and uses voice interaction mode as the way of human-machine co-creation, which is more natural and user-friendly. When users co-create with Co-Art, users have more freedom in this system, and Co-Art supports users to make second attempts to edit drawings using drawing board tools based on completing one creation made through voice input, and AI will continue to understand users' behaviors to complete new creations on this basis. Through interactive mutual learning, each art creation made by the user and AI is unique, which expands the human imagination through those co-created drawing works.

Another result of this paper is a usability test and a summary of user testing methods for children's imaginative development tools. Firstly, a comparison test was designed and pre-tested using Williams Prefer Measurement Forms, and grouped according to scores to avoid the influence of extraneous factors on the test results. The experimental group was then given a co-creation experience with Co-Art and performed the same tasks as the control group. The results are then scored by experts and statistically analyzed to obtain the results.

D. Future Plans

There are also some areas in this article that could be further improved. On the one hand, the interaction design of Co-Art could be enhanced in a targeted way for the habits and needs of children, thus increasing its appeal to children and improving the user experience. The current Co-Art is an experimental demo to verify that it helps develop children's imagination. So the focus at this stage is on the full functionality and proof of the product's usefulness, but it is not a perfect product. The next step will be to improve the product's interaction and interface design in a targeted manner based on more research on children's interests and usage habits.

On the other hand, although we executed user testing for this paper, the number of subjects was relatively small. This is because the period during which this study was conducted coincided with the summer holidays in China, and COVID-19 did not completely disappear, making it difficult to find a large number of children who met the requirements to be tested simultaneously. If the opportunity arises, we will conduct a larger-scale user test to demonstrate Co-Art value further.

VII. CONCLUSIONS

Project Co-Art has produced a human-computer co-creation system for improving children's imagination based on artificial intelligence methods such as generative adversarial networks and cross-modal text-image matching techniques, combined with advanced human-computer interaction concepts, to build a new bridge for many children who lack imagination. Specifically, the contributions of this paper are:

1) in-depth research on the current status of research on tools that assist in improving children's imagination, comparing and summarizing the advantages and disadvantages of multiple products of the same type, and digging out and proposing the latest research directions;
2) based on the design concept of human-computer interaction, a child-friendly operation process is carefully designed to enhance the user experience of the Co-Art system, which provides subsequent related research;
3) used a variety of the latest advanced AI technologies to create the kernel of the Co-Art system and encapsulated it with Web technology, making the Co-Art system not only powerful but also versatile and compatible for multi-platform use and multi-mode drawing;
4) cleverly improved the Williams Prefer Measurement Form and proposed a testing workflow for measuring the performance of human-computer co-creation tools to enhance children's imaginative problems. This workflow demonstrated the validity of the Co-Art system and provided a test and control template for subsequent studies of the same type. In the future, we will continue to expand this project to dig deeper into the pain points of the field, further increase the functionality of the Co-Art system, and optimize the AI kernel for more robust performance.

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