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Collaborative Sketching: Human-AI Collaboration Modes for Enhancing Designers' Performance and Experience in Sketching

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***Abstract*—The rapid development of artificial intelligence (AI) technology is changing the working patterns of designers. AI is becoming a key collaboration partner for designers, supporting them in performing design tasks and inspiring creative thought. Although studies have investigated the collaborative framework between designers and AI, its guidance for specific design practices is limited. This study proposes three designer-AI collaboration modes with typical operable processes during sketching. We conducted a user experiment to compare the effects of different collaboration modes on the quantity, novelty, variety of design outcomes, and the designer's experience. The results show that the collaboration modes can significantly affect the sketch's quantity and variety, as well as the designer's overall satisfaction. Our study focuses on the sketching stage and mainly contributes to bridging the theoretical research and design practice regarding designer-AI collaboration.**

***Index Terms*—design sketching, designer-AI collaboration, generative AI, product design methods**

I. Introduction

The rapid development of artificial intelligence (AI) technology is changing the working patterns of designers. AI is becoming a key collaboration partner for designers, supporting them in not only performing tasks such as information retrieval, data processing, idea visualization, and style transfer [1], but also inspiring their creative thought [2]. Existing research on the designer-AI collaboration framework mainly concentrates on basic theoretical frameworks [3][4][5] and provides limited guidance for specific design practices.

To help bridge the theoretical research and design practice, this study focuses on the sketching stage and proposes three designer-AI collaboration modes with typical operable processes during sketching: visual-aid, subcontract, and co-creation. We conducted an experiment involving 30 participants to compare the effects of different collaboration modes on the quantity, novelty, variety of design outcomes, and the designer's experience. Results show that the co-creation mode performs best in enhancing the sketch quantity and overall satisfaction, while the visual-aid mode produces sketches with the most variety. Our findings contribute to exploring better design workflow based on designer-AI collaboration.

II. Related Works

A. Designer-AI Collaboration

The role of AI in the design process is evolving from a mere auxiliary tool to a vital collaboration partner for designers. AI and designers have complementary strengths: human designers excel in problem insight and strategic thinking [6], while AI usually outperforms them in tasks like information retrieval, data processing, idea visualization, and style transfer [1]. Consequently, designers can use AI to broaden their creative reach and enhance AI's performance by inputting their expertise and tacit design knowledge, thus achieving a win-win situation. Although concerns about "AI replacing human labor" remain, prioritizing collaboration over competition is viewed as more advantageous for improving the capabilities of humans and AI to coexist and co-create [6].

Designer-AI collaboration has attracted increasing attention from researchers. At the beginning of this century, Parasuraman et al. [7] proposed a human-computer trade-off model situated between complete human autonomy and complete computer autonomy. They maintained the assumption of zero-sum competition in human-computer dynamics. Later, Muller et al. [5] noted that the human-AI relationship involves not only competition but also a collaborative growth of both human and AI initiatives. To explain the creative process in the AI era, Wu et al. [6] proposed the human-AI co-creation model and the concept of AI creativity. Although many studies have highlighted AI's potential in design and the significance of human-AI collaboration, current research primarily focuses on improving the theoretical frameworks for human-AI collaboration and provides limited guidance for design practices. As sketching is foundational to any design process, examining the designer-AI collaboration mode in this context may provide valuable insights into the challenges AI poses for design [8].

B. Design Sketching with AI

Sketching is a vital part of the design process [9]. Its specific functions include supporting design communication [10], externalizing and visualizing problems [11], facilitating iterative reinterpretation [12], refining ideas [13], etc. Generally, sketching serves as a visual thinking tool and helps stimulate designers' creativity [14].

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The rapid development of AI technology, particularly generative AI (GenAI), empowers sketch creation in various aspects. GenAI is a branch of AI that focuses on content generation. It has transformed the production of text, images, videos, etc. When it comes to design, first, AI functions as a creative stimulation tool [15] that generates diverse multimodal content and aids in solving fixation effects [16]. Second, AI offers an efficient image editing tool, such as the AI retouching function in Adobe Photoshop, which enables designers to develop and iterate their sketches quickly. Third, to further boost efficiency, AI encourages designers to improve their AI workflow. However, the uncertainty of AI capabilities and the complexity of its outputs make it challenging for designers to grasp AI's ability boundary in sketching [8]. It also raises the demand for designer's ability to plan their collaboration mode with AI.

III. Designer-AI Collaboration Modes for Design Sketching

Optimizing the designer-AI collaboration mode is essential to enhance designer-AI collaboration efficiency during sketching. The benefits of a well-structured division of labor and workflow have been demonstrated in the case of comparing the waterfall model and the agile development framework.

To describe potential designer-AI collaboration modes in sketching, we propose two dimensions: accessibility of the design object and accessibility of the design process. The two dimensions decompose the domains of power for designers and AI [7][5]. As shown in Fig. 1, the vertical axis represents design object accessibility, indicating the proportion of design tasks accessible to AI; the horizontal axis represents design process accessibility, related to the time of AI's intervention in conceptualization [6]. We integrate these dimensions to distinguish designer-AI collaboration modes during sketching and get three modes: visual-aid, subcontract, and co-creation, ranked by AI initiative [5].

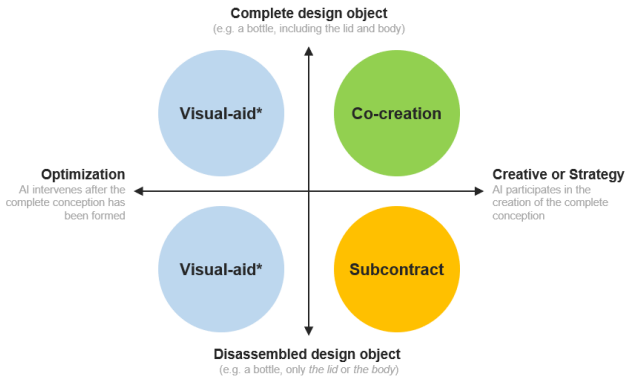

Fig. 1. Designer-AI Collaboration Modes for Design Sketching.
*As for optimization modes, we don't distinguish whether the design object processed by AI is complete. Limited by current technological conditions, designers still face challenges in precisely modifying sketches with mainstream models like DALL·E 3, Stable Diffusion, and Midjourney.

The typical operational processes for the three collaboration modes are illustrated in Fig. 2.

- **The visual-aid mode**. AI merely serves as a sketch optimization assistant for the designers and lacks the initiative to influence conception. This mode features one-way commands and mostly includes a single round of dialog.
- **The subcontract mode**. Due to a clear division of labor, AI assists designers with some easy design tasks and possesses some initiative to influence partial conception. This mode features one-way task assignment and mostly includes a single round of dialog.
- **The co-creation mode**. AI and designers collaboratively take responsibility for the complete design task and inspire each other throughout the design process. AI's initiative increases further. This mode features continuous two-way communication and includes multiple rounds of dialog.

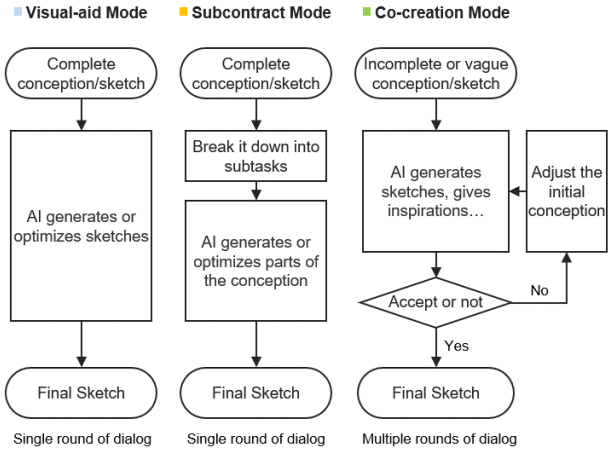

Fig. 2. Typical Processes of the Three Designer-AI Collaboration Modes.

IV. Methods

In the following section, we conducted a user experiment to compare the effects of different collaboration modes on the design outcomes (quantity, novelty, and variety) and the designer's experience. The only independent variable was the designer-AI collaboration mode.

A. Participant

We recruited 30 participants (16 females, 14 males, mean age = 22.17, SD = 1.56). They were students from design disciplines such as industrial design, product design, and digital media arts, each with at least two years of design experience (M = 3.13, SD = 1.11). They all had basic experience with AI products and had used AI tools for no more than 10 hours in the last three months.

B. Procedure

Our experiment utilized BingAI platform equipped with OpenAI's GPT-4 and DALL·E 3. Before the experiment, all participants had 10 minutes to familiarize themselves with the AI platform and the process.

We employed a Latin square design to organize the participant grouping and task order. Participants were randomly divided into six groups (Fig. 3), and each was required to experience the three collaboration modes in a specified order to minimize impacts from learning effects and fatigue. The design tasks differed in objects but had similar complexity in the design object and application scenario. As in Fig. 4, each task lasted 30 minutes, with a 15-minute break in between. During the break, they completed a Net Promoter Score (NPS) questionnaire to report overall satisfaction. When all tasks were completed, participants received a semi-structured interview to report on their evaluation of communication efficiency, AI-generated content quality, and collaboration fluency.

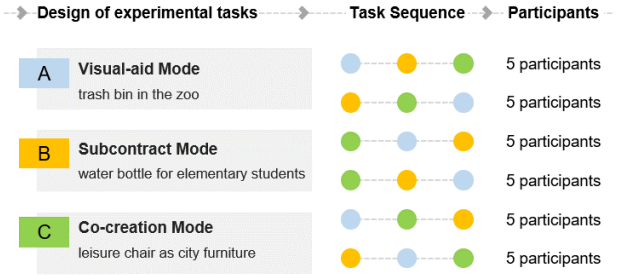

Fig. 3. Tasks and Participants Grouping for the Experiment.

C. Evaluation

To facilitate the observation of user behavior, we recorded the computer interface and AI-generated results throughout the experiment. The evaluation covered both design outcomes and user experience.

Design Outcomes. Dependent variables included the quantity, novelty, and variety of sketches. The formula for novelty [17] is (1), where m is the number of key functions or features, f is the weight, and S is the score allocated to different proposals for specific functions. The formula for diversity [17] is (2), where m is the number of key working principles, f is the weight, S is the scores allocated to specific levels of the working principle, b is the number of branches at a specific level, and n is the total number of sketches.

$$M_1 = \sum_{j=1}^{m} f_j S_{1j} \tag{1}$$

$$M_2 = \sum_{j=1}^{m} f_j \sum_{k=1}^{4} S_k b_k / n \tag{2}$$

User Experience. We used the Net Promoter Score (NPS) questionnaire to assess participants' overall satisfaction with

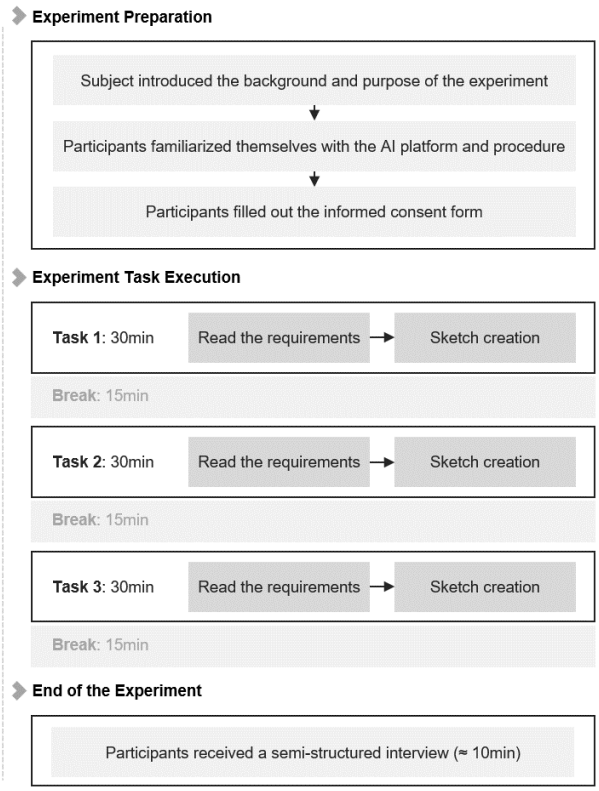

Fig. 4. Experiment Procedure.

the three collaboration modes. NPS is a customer feedback tool that asks respondents how likely they are to recommend a product or service, helping researchers measure user loyalty and satisfaction. To calculate the NPS value, we subtracted the percentage of detractors (scores 0-6) from the percentage of promoters (scores 9-10). Moreover, the results from the semi-structured interview constituted valuable supplements to the quantitative results of both design outcomes and user experience.

V. Results and Discussion

Design Outcomes. The experimental data are shown in Table I and Fig. 5. The Shapiro-Wilk W test indicates a normal distribution of data. According to one-way ANOVA, we found that the co-creation mode produced the most sketches and the subcontract mode produced the least ($p < 0.001$). There was no significant difference in novelty ($p = 0.16$). As for variety, the visual-aid mode achieved the highest average score, and the co-creation mode achieved the lowest ($p < 0.001$). Overall, (i) the visual-aid mode exhibited the most variety, largely due to AI's ability to supplement and optimize design details automatically; (ii) the co-creation mode generated the most sketches but the least diversity, as some participants reported a tendency to iterate on specific ideas and neglect exploration for diversity; (iii) the subcontract mode generated the fewest

sketches, primarily due to the contradiction between uncertain AI-generated results and designers' expectations.

User Experience. Participants reported the highest overall satisfaction with the co-creation mode and the lowest with the visual-aid mode ($p < 0.001$). In the co-creation mode, designers engaged in deep interaction with AI during data collection and sketch generation, allowing AI to complete tasks in ways more aligned with designer requirements, thus enhancing usability and collaboration fluency ratings. In the visual-aid mode, users passively filtered AI-generated results, easily resulting in dissatisfaction if the outputs did not meet expectations.

TABLE I
MEANS OF NUMBER OF SKETCHES, NOVELTY, VARIETY, AND NPS OF OVERALL SATISFACTION.

Evaluation Dimensions	**Experiment Groups**		
	Visual-aid	***Subcontract***	***Co-creation***
Sketch Quantity	7.88	4.00	12.63
Novelty	4.84	5.17	5.01
Variety	9.56	8.55	4.01
NPS of Overall Satisfaction	-40.00%	13.33%	23.33%

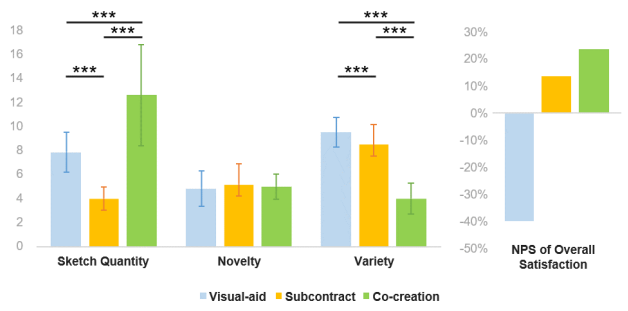

Fig. 5. Visualization of Experiment Results: Number of Sketches, Novelty, Variety, and NPS of Overall Satisfaction.

VI. CONCLUSION

This study proposes three designer-AI collaboration modes with typical operable processes during sketching. The user experiment shows that the collaboration modes significantly affect the quantity and variety of design outcomes and overall satisfaction, but have no significant impact on the novelty. The co-creation mode performs best in enhancing the sketch quantity and overall satisfaction, while the visual-aid mode produces sketches with the most variety. Our study strengthens the evidence for AI's potential as an effective design collaborator and helps designers improve the sketch-creation workflow with AI. Future studies could further refine the processes of the existing modes and assess the conclusions' applicability for other stages except sketching and designers of different levels, thus providing broader theoretical and practical support for human-AI collaborative design.

REFERENCES

[1] Y. Shi, T. Gao, X. Jiao, and N. Cao, "Understanding design collaboration between designers and artificial intelligence: a systematic literature review," *Proceedings of the ACM on Human-Computer Interaction*, vol. 7, no. CSCW2, pp. 1–35, 2023.

[2] T. Lawton, K. Grace, and F. J. Ibarrola, "When is a tool a tool? user perceptions of system agency in human–ai co-creative drawing," in *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, 2023, pp. 1978–1996.

[3] A. Erlei, A. Sharma, and U. Gadiraju, "Understanding choice independence and error types in human-ai collaboration," in *Proceedings of the CHI Conference on Human Factors in Computing Systems*, 2024, pp. 1–19.

[4] L. Yan, V. Echeverria, G. M. Fernandez-Nieto, Y. Jin, Z. Swiecki, L. Zhao, D. Gašević, and R. Martinez-Maldonado, "Human-ai collaboration in thematic analysis using chatgpt: A user study and design recommendations," in *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*, 2024, pp. 1–7.

[5] M. Muller and J. Weisz, "Extending a human-ai collaboration framework with dynamism and sociality," in *Proceedings of the 1st Annual Meeting of the Symposium on Human-Computer Interaction for Work*, 2022, pp. 1–12.

[6] Z. Wu, D. Ji, K. Yu, X. Zeng, D. Wu, and M. Shidujaman, "Ai creativity and the human-ai co-creation model," in *Human-Computer Interaction. Theory, Methods and Tools: Thematic Area, HCI 2021, Held as Part of the 23rd HCI International Conference, HCII 2021, Virtual Event, July 24–29, 2021, Proceedings, Part I 23*. Springer, 2021, pp. 171–190.

[7] R. Parasuraman, T. B. Sheridan, and C. D. Wickens, "A model for types and levels of human interaction with automation," *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans*, vol. 30, no. 3, pp. 286–297, 2000.

[8] Q. Yang, A. Steinfeld, C. Rosé, and J. Zimmerman, "Re-examining whether, why, and how human-ai interaction is uniquely difficult to design," in *Proceedings of the 2020 chi conference on human factors in computing systems*, 2020, pp. 1–13.

[9] N. Cross, "Natural intelligence in design," *Design studies*, vol. 20, no. 1, pp. 25–39, 1999.

[10] S. A. Scrivener and S. M. Clark, "Sketching in collaborative design," *Interacting with virtual environments. Wiley, Chichester, UK*, 1994.

[11] D. Kernohan, "Externalizing the design process," *Design Studies*, vol. 2, no. 1, pp. 27–32, 1981.

[12] D. A. Schon and G. Wiggins, "Kinds of seeing and their functions in designing," *Design studies*, vol. 13, no. 2, pp. 135–156, 1992.

[13] G. F. Smith, "Idea-generation techniques: A formulary of active ingredients," *The Journal of Creative Behavior*, vol. 32, no. 2, pp. 107–134, 1998.

[14] M. Hua, "The roles of sketching in supporting creative design," *The Design Journal*, vol. 22, no. 6, pp. 895–904, 2019.

[15] P. Karimi, J. Rezwana, S. Siddiqui, M. L. Maher, and N. Dehbozorgi, "Creative sketching partner: an analysis of human-ai co-creativity," in *Proceedings of the 25th international conference on intelligent user interfaces*, 2020, pp. 221–230.

[16] D. P. Moreno, M. C. Yang, A. A. Hernández, J. S. Linsey, and K. L. Wood, "A step beyond to overcome design fixation: a design-by-analogy approach," in *Design Computing and Cognition'14*. Springer, 2015, pp. 607–624.

[17] J. Han, H. Forbes, and D. Schaefer, "An exploration of how creativity, functionality, and aesthetics are related in design," *Research in Engineering Design*, vol. 32, no. 3, pp. 289–307, 2021.