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THE DESIGN AND ASSESSMENT OF AN AI INTERACTIVE INSTALLATION BASED ON IMAGE STYLE TRANSFER AND FACIAL RECOGNITION FOR CULTURAL HERITAGE LEARNING

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ABSTRACT
Artificial intelligence (AI) has proven to be an effective tool for the public sector in preserving, analyzing, managing, and presenting cultural heritage. However, little research has focused on the specific impact of AI on public engagement, particularly regarding cultural heritage learning. This article aims to investigate the impact of AI on the public's cultural heritage learning through the design and evaluation of an interactive installation that combines image style transfer and facial recognition technologies. We focused on assessing participants' performance in the cultural heritage learning process and learning outcomes in terms of behavior and knowledge through conversation analysis, interviews, and questionnaires. The results demonstrated that the interactive installation fostered user-generated learning dialogues across five main categories: Perceptual talk (30.60%), Strategic talk (24.89%), Connecting talk (16.40%), Conceptual talk (15.22%), and Affective talk (12.90%). Furthermore, it facilitated the acquisition of cultural heritage knowledge and behavior of sharing cultural heritage on offline and online platforms post-experiment.

Keywords: Artificial Intelligence, Cultural Heritage, Interactive Installation, Image Style Transfer, Facial Recognition

1 INTRODUCTION

Cultural heritage is a vital source of identity, creativity, and social cohesion for individuals and communities [1]. Professionals in the cultural heritage field have widely adopted technology to enhance the access, preservation, management, and communication of cultural heritage while ensuring interoperability and noninvasiveness. One effective method for achieving these goals is the use of AI. AI models can assist cultural heritage workers in preventing and repairing damage caused by natural disasters [2][3], processing and comprehending cultural heritage data more efficiently [4] [5] and generating more personalized and realistic data to increase public interest in cultural heritage [6] [7].

With the rapid development of deep learning networks, image style transfer has emerged as a promising technique for cultural heritage applications. Image style transfer is a technique that enables the transformation of original images into specific artistic styles and provides opportunities for artistic analysis and heritage development. For example, Dunhuang Academy uses image style transfer to make e-Heritage images more appealing by a mini program that lets users design their own scarves with dome elements [8]. Similarly, Zhang and Romainoor used image style transfer to create Pop art style New Year prints with high quality, enhancing the appeal of this cultural heritage among young people [9]. However, these applications still lack in-depth interaction with users, so we propose an innovative way of interaction.

Facial recognition technology is a non-contact and convenient technology, widely used in recognizing and analyzing various public datasets [10] which suits public cultural heritage domains. It can be applied to protect and manage cultural heritage by scanning visitors' faces for security and access purposes [11]. Some research also uses facial recognition to analyze facial features and explore human images and traits across cultures, regions and times [12]. However, despite significant advancements in AI applications for cultural heritage, research investigating their specific impact on the public, especially in terms of cultural heritage learning, is limited.

Public cultural heritage learning often takes place in informal environments such as museums, so this field is closely related to informal learning. Previous research has examined how technology affects museum learning outcomes using meta-analysis [13]. Some researchers have also focused on exploring the specific effects and evaluation of the application of virtual reality or augmented reality to cultural heritage [14][15]. However, there is limited research on the impact of AI on cultural heritage learning. In addition, evaluating learning outcomes in informal learning environments poses challenges within the educational community [16][17], because informal learning activities are characterized by autonomy and freedom, with learning outcomes emerging at various stages, encompassing diverse aspects such as knowledge, skills, attitudes, emotions, and behaviors [18]. Therefore, it is necessary to adopt more diverse evaluation methods to study the learning process and outcomes of cultural heritage.

This article aims to investigate the impact of AI on the public's cultural heritage learning process and outcomes through the design and evaluation of an interactive installation that combines image style transfer and facial recognition technologies. More specifically, based on the cultural heritage content (pattern features and cultural background) of this case and the pre-experiment result of the interactive installation (triggering dialogue), we choose to focus on the users' learning dialogue and thinking during the learning process, as well as their knowledge acquisition and sharing behavior in the learning outcomes. Therefore, our research questions are as follows:

Q1: How does an interactive installation that applies image style transfer and facial recognition technology affect the cultural heritage learning process?

Q2: How do participants perform in cultural heritage learning outcomes in terms of behavior and knowledge when using an interactive installation that applies image style transfer and facial recognition technology?

To answer the above research questions, we conducted experiments in a controlled laboratory setting by conversation analysis and interviews for learning process (Q1), and questionnaires for learning outcomes (Q2), and then captured data during the experience, after the experience, and two weeks following the conclusion of the experiment.

2 INTERACTIVE INSTALLATION DESIGN

2.1 Interactive installation description

The cultural heritage resources utilized in this case are derived from the Changsha kiln patterns. The Changsha kiln is a type of underglaze porcelain that exemplifies the achievements of Tang Dynasty porcelain-making technology. The kiln pioneered the decoration of ceramics with painting and inherited from the traditional ink and brush of Chinese calligraphy and painting while integrating exotic patterns, forming a unique system of expression that influenced later generations [19].

Figure 1. Changsha Kiln interactive installation

The Changsha Kiln interactive installation aims to provide visitors with a new cultural heritage experience by capturing visitors' facial expressions and displaying scene images filled with different styles of Changsha kiln patterns in real-time. The installation comprises a screen, camera, printer, mobile phone, and computer (Figure 1). When a visitor approaches the screen and is captured by the camera, the original scene image containing the user will be transformed into a specific Changsha kiln style image. At the same time, corresponding cultural heritage information will be displayed. The style of the scene image changes when the visitor tries different expressions. Additionally, the installation provides visitors with the opportunity to obtain a photo as a souvenir by pressing the "print" button on their mobile phones at a satisfactory moment.

2.2 Interactive installation design

The interactive installation design process mainly consists of three parts (Figure 2). To achieve scene stylization, it was necessary to determine suitable Changsha kiln patterns that would effectively communicate cultural heritage knowledge and yield good image style transfer results. To achieve this, we invited three experts to screen and classify over 1,000 different artistic styles of Changsha kiln patterns. We then tested different types of patterns for image style transfer and consequently selected four typical abstract Changsha kiln artistic style patterns (Figure 3).

To enable real-time image style transfer, we used a knowledge distillation technique to train a compact transformer-based network that mimics the style transfer capabilities of the larger Visual Geometry Group (VGG) network while significantly reducing computational demands. Knowledge distillation transfers knowledge from a large, pre-trained model (in this case, the VGG network) to a smaller model, preserving the stylistic details of the Changsha kiln patterns while allowing quick, real-time processing. This streamlined model ensures fluid user interaction, as style-transferred images are rendered almost instantly.

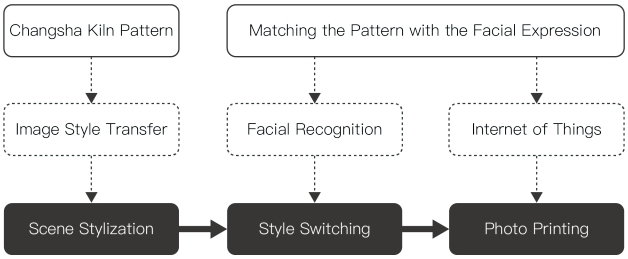

Figure 2. Design process

Figure 3. Four typical Changsha kiln patterns and corresponding four effects of image style migration

In terms of interactive design, we utilized facial recognition technology to enable the switching between different styles. To establish the correspondence between different expressions and different style patterns, we first selected four relatively common expressions from an existing expression library and then invited 30 participants to match different expressions with different style patterns based on their intuition. Test results showed that participants had a clear tendency as shown in Figure 4.

For facial recognition, we integrated the Dlib face detection framework due to its high accuracy and efficiency in facial feature extraction. Dlib's deep learning-based methods enable precise detection and tracking of facial landmarks with minimal latency, which is essential for smooth user interaction in real time. This framework was configured to recognize and categorize four common expressions, each mapped to a specific Changsha kiln style. When a user's expression is detected, the image classification network applies the corresponding style, enabling expression-based style transfer and enhancing the responsiveness of the interactive experience.

To enhance user engagement, the installation allows users to print their style-transferred images as keepsakes. Using Internet of Things (IoT) technology, we implemented a remote printing feature that enables users to activate a button on their mobile devices, which communicates with the installation's computer system to print style-transferred images from computer screenshots.

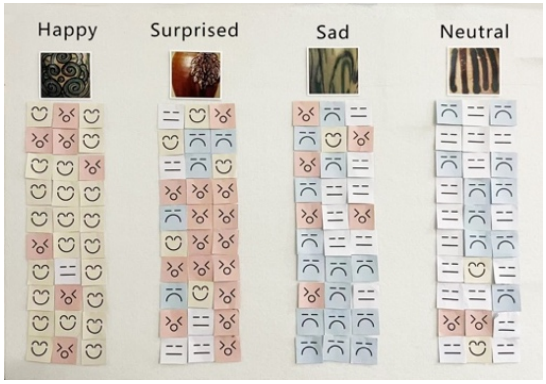

Figure 4. The result of matching facial expressions with patterns

3 INTERACTIVE INSTALLATION EVALUATION

3.1 Experimental methodology

Our research focuses on the learning process and outcomes of cultural heritage. For the learning process, we selected the method of conversation analysis to code and categorize recorded conversations based on Sue Allen's learning dialogue coding scheme, which combines socio-cultural and cognitive science perspectives, including five main categories of Perceptual talk, Strategic talk, Conceptual talk, Affective talk, and Connecting talk [20]. Furthermore, we conducted interviews to further elicit users' thoughts and feedback on the learning process.

We also assessed learning outcomes by distributing knowledge questionnaires before and after the experiment, which included questions on Changsha Kiln pattern recognition, cultural understanding, and self-reported learning. Finally, two weeks after the experiment, we distributed a follow-up questionnaire to explore related discussions and sharing behaviors to verify whether users discussed and shared their experience, the interactive installation, related technology, and Changsha kiln.

3.2 Experimental procedure

We conducted a laboratory experiment involving 24 university students aged 20-25, including 9 males and 15 females. Participants were grouped into threes to experience the interactive installation, and they knew each other beforehand. This technique aimed to simulate typical public visitation scenarios, such as those in museums and exhibitions, where small groups of two to three visitors explore and interact freely.

Prior to commencing the experiment, we distributed a knowledge questionnaire to evaluate participants' understanding of Changsha Kiln. Subsequently, we introduced the functions of the interactive device to each group and allowed them to take turns to experience it individually, followed by 3 people in the group experiencing it together. Assistance was provided where necessary, and all conversations between participants were recorded for analysis.

After the experience, participants completed the same knowledge questionnaire on Changsha kiln. We then conducted individual interviews to further obtain their feedback on the cultural heritage learning process. Finally, two weeks after the experiment, we administered a follow-up questionnaire.

4 RESULTS AND DISCUSSION

4.1 Cultural Heritage learning process

We collected audio recordings of the experience process from 24 participants who were divided into eight groups of three. We categorized the learning dialogues into five categories and calculated the average percentage of each type among all the learning dialogues (Figure 5). On average, each group produced 10 learning-related dialogues during the experiment.

Perceptual talk was the most prevalent type, accounting for 30.60% of the dialogues. This behavior involved identifying, naming, quoting, and describing features. For example, Participant 1a stated, "This color is a ceramic base"; and Participant 8a stated, "This effect is abstract."

Strategic talk, the second most common type (24.89%), involved how to use the installation or evaluating one's own or a partner's performance and behavior. For example, Participant 4b said, "I'm having a bit of a hard time getting this effect."
Connecting talk accounted for 16.40% of the dialogues and included life-connection, knowledge-connection, and Inter-installation connection. For example, Participant 2c said, "A visual work combining animals and flowers that I've seen online before" and Participant 7b: "I once went to the museum and saw the Changsha kiln pattern."
Conceptual talk accounted for 15.22% of the dialogues and related to the participant's cognition and interpretation of things they paid attention to. For instance, Participant 4a: "The effect with the green dots occurs when you make a smiling face."; Participant 5c "The pattern is supposed to come from on a jar."
Affective talk (12.90%) captured all emotional expressions, with most users pleasantly surprised by the experience. For example, Participant 6a: "My expression is just so cool"; Participant 6c: "Wow, this is a magic effect."

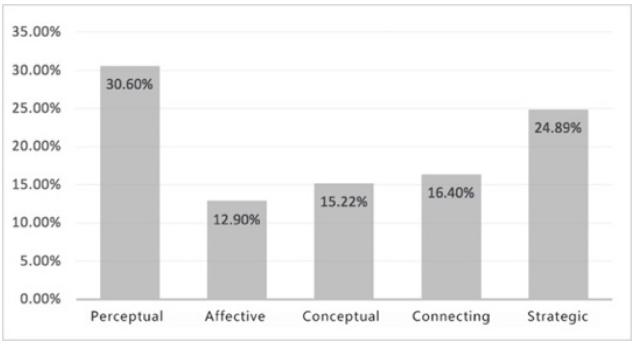

Figure 5. The average proportion of each category among all learning dialogues

Subsequently, interviews were conducted to further explore the participants' learning process. The facial recognition interaction method was found to be interesting, and participants enjoyed trying out different expressions to generate stylized images. Moreover, this method provided sustained engagement by encouraging people to try out all cultural heritage pattern effects instead of exiting after experiencing one or two effects. In addition, this method actively promoted discussion among participants. For example, they may comment on their own/peer's behavior or share experiences of making expressions. However, only a few people expressed discomfort with making too many facial expressions in public. Overall, the novelty and challenge of this interaction motivated the experiencers to keep completing the task.
The image style transfer technique also motivated participants to actively discuss the experience, the cultural heritage, or the technique effects. Participants mentioned that "this reminds me of a photo I took with my friends"; "these technique effects are like the facial effects that are very popular on TikTok". In addition, questions were asked: "Are these effects specific to the Changsha kiln patterns?"; " Could other patterns of porcelain achieve similar effects? ". Finally, some suggested that a stronger stylized effect could be created, while others preferred a softer effect.
The above analysis leads to the conclusion that the entire experience actively prompted users to engage in learning dialogues, most of which focused on the interactive installation and personal experiences. However, regarding cultural heritage, this installation triggered the participants' attention to Changsha Kiln patterns and some associations on patterning features but lacked complex cultural reasoning. For example: although we provided textual knowledge about artistic characteristics and craftsmanship of Changsha kiln, most participants did not read it carefully, and there was no discussion of the content. This may be because participants were more interested in exploring the novel and challenging facial recognition interaction than in learning about the historical and cultural background of Changsha kiln. This suggests a need to balance the engagement and educational aspects of interactive installations for cultural heritage.

4.2 Cultural heritage learning outcomes

For the knowledge dimension, we conducted statistical analysis on the Changsha Kiln knowledge questionnaire scores administered before and after the experiment, revealing that the participants'

average score increased by 15.53%, with pattern recognition improving by 12.12% and cultural understanding by 3.41%. These findings highlight the significance of the interactive installation in facilitating cultural heritage learning, with more prominent effects observed in intuitive pattern recognition. Additionally, most participants reported an increase in their understanding of Changsha Kiln through self-report, particularly those with less prior knowledge.

For the behaviors dimension, analysis of questionnaires issued two weeks after the experiment revealed that most participants engaged in related discussions and sharing activities. Specifically, 79.17% discussed related topics, with 66.67% sharing their experience, 41.67% discussing the interactive installation, 33.33% discussing related technology, and 16.67% discussing topics related to Changsha Kiln (Figure 6). In addition, 25% of participants shared related topics on personal social media, with 16.67% sharing their experience, 8.33% sharing knowledge about Changsha Kiln, and 4.17% sharing information about the interactive installation and related technology (Figure 7). These findings indicate that participants share cultural heritage consciously or unconsciously to some extent. Although people may not directly discuss complex or professional knowledge, interactive experiences closely related to personal experience create opportunities for discussing and sharing cultural heritage.

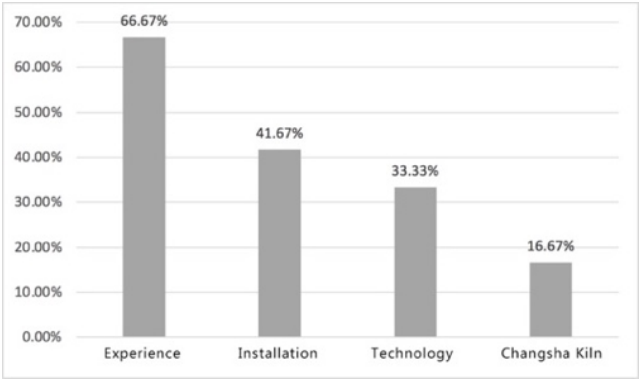

Figure 6. Proportion of discussions

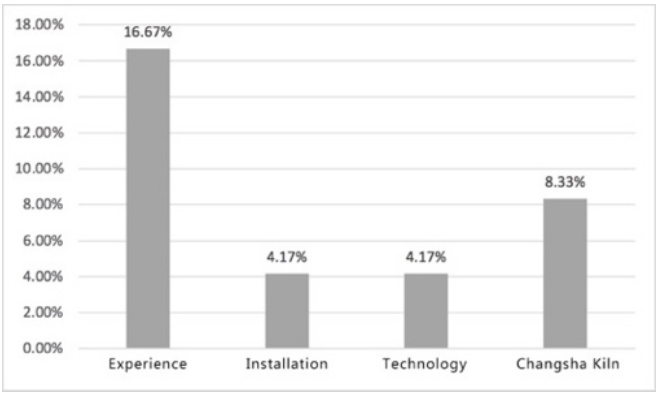

Figure 7. Proportion of social network sharing

5 CONCLUSIONS

This article explores the effectiveness of AI applications in the cultural heritage learning process and outcomes for the public through the design and evaluation of an interactive installation that utilizes image style transfer and facial recognition technology. The results demonstrate that the installation effectively promotes participants to engage in relevant learning dialogues during the experience, covering five categories: Perceptual talk (30.60%), Strategic talk (24.89%), Connecting talk (16.40%), Conceptual talk (15.22%), and Affective talk (12.90%). As for learning outcomes, we found that it improved participants' knowledge of Changsha kiln and stimulated them to actively discuss and share this experience, relevant technologies, or cultural heritage knowledge, indicating the positive impact of the installation on promoting cultural heritage post-experiment.

In conclusion, our research demonstrates that AI technologies such as facial recognition and image style transfer are effective tools for cultural heritage learning. The interactive method of facial expression provides sustained engagement and encourages participants to try out different cultural heritage pattern

effects while discussing their behavior and sharing experiences. Similarly, the image style transfer technique motivates participants to actively discuss the experience, cultural heritage, and technique effects.

We identified a limitation in conveying deeper cultural content, as some users overlooked key textual information. To address this, we recommend enhancing knowledge delivery through audio playback or staff-led guidance [21]. Providing incentives, such as knowledge-based rewards, could also boost engagement with the content [22]. Regardless of the approach taken, designers should prioritize the primary objective of enhancing understanding of cultural heritage.

While this study shows promising results, the absence of a control group limits our findings. Including a control group in future research would provide a clearer baseline for assessing the installation's impact on learning outcomes, thereby strengthening the reliability of our conclusions.

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REFERENCES

[1] Murzyn-Kupisz M. and Dzialek J. Cultural heritage in building and enhancing social capital. *Journal of Cultural Heritage Management and Sustainable Developmen*t, 2013, 3(1): 35-54.

[2] Zeng Y., van der Lubbe J. C. and Loog M. Multi-scale convolutional neural network for pixel-wise reconstruction of Van Gogh's drawings. *Machine Vision and Applications*, 2019, 30(7): 1229-1241.

[3] Danese M., Masini N., Sileo M., et al. Proximal Remote Sensing e Spatial Analysis per la Conservazione delle Pitture Parietali Pompeiane. il Caso del Gymnasium. *Archeomatica*, 2019, 10(2).

[4] Garozzo R., Pino C., Santagati C., et al. Harnessing the power of artificial intelligence for modelling and understanding cultural heritage data. *Impact of Industry 4.0 on architecture and cultural heritage*, 2020: 357-376.

[5] Zhao M., Wu X., Liao H. T., et al. Exploring research fronts and topics of Big Data and Artificial Intelligence application for cultural heritage and museum research. *IOP Conference Series: Materials Science and Engineering,* 2020, 806(1): 012036.

[6] Saihood G. S. W., Haddad A. T. H. and Eyada F. Personalized Experiences Within Heritage Buildings: Leveraging AI For Enhanced Visitor Engagement. *2023 16th International Conference on Developments in eSystems Engineering. IEEE*, 2023: 474-479.

[7] Ocaña-Fernández Y., Valenzuela-Fernández L. A.and Garro-Aburto L. L. Artificial Intelligence and Its Implications in Higher Education. *Journal of Educational Psychology-Propositos y Representaciones*, 2019, 7(2): 553-568.

[8] Yu T., Lin C., Zhang S., et al. Artificial intelligence for Dunhuang cultural heritage protection: the project and the dataset. *International Journal of Computer Vision*, 2022, 130(11): 2646-2673.

[9] Zhang B., Romainoor N. H. Research on artificial intelligence in new year prints: the application of the generated pop art style images on cultural and creative products. *Applied Sciences*, 2023, 13(2): 1082.

[10] Valenti R., Jaimes A. and Sebe N. Facial expression recognition as a creative interface. *Proceedings of the 13th international conference on intelligent user interfaces*. 2008: 433-434.

[11] Ferrato A., Limongelli C., Mezzini M., et al. Using deep learning for collecting data about museum visitor behavior. *Applied Sciences*, 2022, 12(2): 533.

[12] Huber M., Terhörst P., Luu A. T., et al. Verification of sitter identity across historical portrait paintings by confidence-aware face recognition. *2022 26th International Conference on Pattern Recognition (ICPR)*, 2022: 938-944.

[13] Xu W., Dai T. T., Shen Z. Y., et al. Effects of technology application on museum learning: A meta-analysis of 42 studies published between 2011 and 2021. *Interactive Learning Environments*, 2023, 31(7): 4589-4604.

[14] Chong H. T., Lim C. K., Rafi A., et al. Comprehensive systematic review on virtual reality for cultural heritage practices: coherent taxonomy and motivations. *Multimedia Systems*, 2022: 1-16.

[15] Boboc R. G., Bautu E., Gîrbacia F., et al. Augmented reality in cultural heritage: an overview of the last decade of applications. *Applied Sciences,* 2022, 12(19): 9859.

[16] Diamond J., Horn M. and Uttal D H. Practical evaluation guide: Tools for museums and other informal educational settings. *Rowman & Littlefield*, 2016.
[17] Schweingruber H. A. and Fenichel M. Surrounded by science: Learning science in informal environments. *National Academies Press*, 2010.
[18] Hohenstein J. and Moussouri T. Museum learning: Theory and research as tools for enhancing practice. *Routledge*, 2017.
[19] Li, B. H. Changsha kiln volume. *Hunan Art Press*, 2004, 60-70.
[20] Allen S. Looking for learning in visitor talk: A methodological exploration. *Learning conversations in museums*, 2003: 265-309.
[21] Reunanen M., Díaz L. and Horttana T. A holistic user-centered approach to immersive digital cultural heritage installations: Case Vrouw Maria. *Journal on Computing and Cultural Heritage (JOCCH)*, 2015, 7(4): 1-16.
[22] Paliokas I.and Sylaiou S. The use of serious games in museum visits and exhibitions: A systematic mapping study. *2016 8th International Conference on games and virtual worlds for serious applications (VS-GAMES)*. IEEE, 2016: 1-8.