

## ARTICLE

# The random brush reimagined: Artificial intelligence-generated calligraphy, embodied perception, and cultural resonance

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## Abstract

In recent years, artificial intelligence (AI) has increasingly intersected with traditional art forms, introducing new modes of creativity that challenge established esthetic frameworks while expanding the boundaries of artistic expression. Against this backdrop, this study explores the transformative role of AI-generated randomness in Chinese calligraphy, an art form deeply rooted in the philosophical ideals of harmony and balance derived from Confucianism, Daoism, and Buddhism. By leveraging models like Stable Diffusion, AI infuses unpredictable elements into calligraphic creation, challenging established esthetic norms while unlocking novel artistic possibilities. Employing a cross-case comparative and textual analysis approach, this research examines visual-semantic contrasts between representative traditional scripts and AI-generated works, while also investigating the historical evolution of calligraphic esthetics, cultural practices, and cross-cultural reception. The findings reveal that such technological interventions enhance the global accessibility of calligraphy, resonate with younger audiences, expand its dimension of expression, and redefine human engagement with the art form. Results indicate that AI not only democratizes calligraphy but may also stimulate public interest in, and a deeper understanding of, traditional techniques and cultural depth. This study advocates for a dynamic balance between cultural heritage preservation and technological innovation, proposing AI as a cultural gateway to traditional practice, and calls for further exploration of its global cultural implications.

**Keywords:** Artificial intelligence-generated calligraphy; Embodied practice; Randomness in art; Cultural resonance; Esthetic innovation

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**Citation:** Wang K, Yu D. The random brush reimagined: Artificial intelligence-generated calligraphy, embodied perception, and cultural resonance. *Arts & Communication*. 2026;4(1):025170030.  
doi: 10.36922/AC025170030

**Received:** April 26, 2025**1st revised:** September 11, 2025**2nd revised:** September 23, 2025**Accepted:** October 13, 2025**Published online:** October 31, 2025

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## 1. Introduction

### 1.1. Research background and significance

The emergence of digital technology has had a significant impact on handwritten calligraphy, and Chinese character calligraphy is facing a similar situation. Chatting software and emails have become essential in daily life. The aphorisms, such as “the handwriting reflects the person” and “seeing the handwriting is like seeing the person,”

have become symbolic expressions of a bygone era. We can communicate with numerous people and perform multiple tasks simultaneously. However, the advanced techniques of handwritten Chinese calligraphy, which demand prolonged practice and patience to master, are increasingly incompatible with the accelerated rhythms of contemporary life and are gradually being marginalized.<sup>1</sup> At the same time, the appearance of design software has also made calligraphy creation different from the past. Artificial intelligence (AI)-generated fonts can replicate handwritten Chinese calligraphy with considerable accuracy, and lay audiences often struggle to distinguish between an artist's original work and digital imitations.<sup>2</sup> Coupled with the shift in taste, this ancient form of creation, full of artistic and philosophical ideas, is facing a serious predicament.<sup>3</sup>

However, AI might flip the script. Take CallifusionV2<sup>1</sup>, an AI-driven calligraphic generation model developed for this study, as an example: It rethinks the calligraphy of each Chinese character and introduces variations that offer each work a unique visual effect, unlike the old rules of planned strokes.<sup>4</sup> These AI tools enable broader access to calligraphy without any basic calligraphy knowledge. One can now experience digital calligraphy performances of brush art anytime and anywhere, dismantling long-standing limitations.<sup>5</sup> Instead of killing tradition, these tools may catalyze its revitalization.

Integrating advanced virtual reality (VR) is expanding the way of calligraphy teaching and learning. Based on the immersive environment provided by VR, learners can obtain all the details needed to improve calligraphy writing skills by experiencing the tactile issues, such as stroke movement, ink blending, and paper texture. The possibilities of reshaping calligraphy education are revealed by addressing the gap in current VR applications to transmit these subtle tactile signals, improving tactile gloves, and integrating force feedback technology.<sup>6</sup> Exploring how VR applications address these kinds of challenges facilitate the formation of new teaching concepts and global cross-cultural cooperation rather than protecting calligraphy. Meanwhile, the use of Metaverse Intelligent Education Technology (MIET) in calligraphy learning can improve students' learning interest, motivation, and cultural engagement.<sup>7</sup>

Through the vivid learning environment constructed by MIET, learners can watch and control the writing tool through an immersive experience. The entire learning process improves the accuracy of knowledge construction by inspiring the motivation and interest of learners. For

the next generation, the integration of technology and traditional calligraphy not only protects cultural heritage but also adapts modern instructional methods.<sup>8</sup> Thus, the vision of MIET in relation to calligraphy education is expansive.

Furthermore, the value of touch feedback in the teaching process is proven by checking VR methods for real calligraphy training. AI-powered haptic gloves and wearable tools can provide flexible feedback and produce quick, custom details in focus tracking, interest, and skills, enhancing the realism and pedagogical effectiveness of the learning environment.<sup>9</sup> These VR-based methods address the challenges of sharing tactile input, offering new avenues for the preservation and development of classical calligraphy. These steps in VR methods can address the challenges of sharing touch input and create new paths for the protection and growth of traditional calligraphy.

However, it is crucial to recognize that traditional calligraphy is not merely a visual or decorative art form. Its deep cultural core and enduring value lie in the coherent unity of "body-mind-work"—a practice rooted in Confucian ideals of self-cultivation (修身, *xiushen*) and Daoist notions of embodying the Dao (体道, *tidao*). This embodied practice stands in essential contrast to AI-generated calligraphy: while the latter produces images through algorithmic parameter learning, traditional calligraphy unfolds as a holistic process from bodily perception (force, emotion, breath) to brush-and-ink expression and ultimately, cultural transmission.

This distinction is not a rejection of AI, but rather a clarification of two fundamentally different modes of creation and meaning-making. It allows us to define their respective roles more precisely: AI functions as an innovative extension medium for calligraphy, while the embodied practice remains the core foundation of its cultural ontology. Recognizing this boundary is essential for exploring, in a nuanced way, how technology can revitalize calligraphic art without diluting its cultural depth—the central aim of this study.

## 1.2. Research objectives and core problem statement

Amidst the backdrop of capitalization and the evolution of AI, intelligent productivity has become a new driving force for social development. As one of the oldest carriers of philosophical expression, Chinese calligraphy is transforming its informational and esthetic dimensions. Diffusion models introduce algorithmic randomness into calligraphic abstraction, disrupting long-standing principles of harmony, balance, and predictability of change—a shift documented in recent studies on generative

<sup>1</sup> CallifusionV2: A custom AI model for generative calligraphy, developed by the authors using Stable Diffusion architecture and trained on 10,000 high-resolution calligraphic samples.

esthetics.<sup>5</sup> This unpredictability has been shown to alter the perception and emotional engagement of viewers with traditional art forms,<sup>10</sup> including calligraphy.

Building on these technological developments and the conceptual distinction between the embodied practice of traditional calligraphy and the algorithmic generation of AI, this study seeks to explore how digital innovation can coexist with cultural continuity, rather than displace it. Rather than treating AI as a replacement for human creativity, we position it as an innovative extension medium—a technological conduit that, through visual novelty and broad accessibility, may paradoxically redirect attention toward the bodily discipline and philosophical depth of traditional calligraphy. Therefore, this study investigates how algorithmic randomness challenges established visual norms in composition, stroke dynamics, and stylistic coherence, while simultaneously generating novel esthetic experiences in a digitally connected era. It further examines how these AI-generated works influence emotional resonance and cognitive interpretation, particularly among younger, tech-savvy audiences who may encounter calligraphy for the first time through digital interfaces.

At its core, this study asks how AI can stimulate renewed cultural engagement without reducing calligraphy to mere digital imagery. It explores the conditions under which technological intervention might not erode, but instead amplify awareness of the body-mind-work continuum—the Confucian ideal of self-cultivation and Daoist notion of embodying the Dao—that defines the art's cultural ontology. To this end, we also propose design strategies for integrating elements of embodied practice, such as recorded brushwork movements, breath-synchronized writing, or the transmission of vital energy (气, *qi*), into AI calligraphy applications, ensuring that the sensory and spiritual dimensions of the tradition remain legible in digital form. Ultimately, this work aims to establish a balanced framework in which technical experimentation and cultural fidelity are not opposing forces, but interdependent vectors in the evolution of an ancient art form.<sup>11</sup> By examining the interplay between algorithmic unpredictability and cultural memory, we seek to understand how the random brush might, against expectation, deepen our connection to tradition in the age of AI.

### 1.3. Structure of the study

By focusing on the impact of randomness in AI-generated Chinese calligraphy, this study employed a wide range of strategies to assess its historical, psychological, and cross-cultural aspects. The study began by examining the history of calligraphy esthetics, reconsidering established guiding

principles, while checking the current impact of virtual technologies and AI on esthetic perception. The study compared Eastern and Western perceptions of AI-generated calligraphy, showing the interactions between psycho-emotional responses, social context, and randomness, and highlighted the nuances of cross-cultural communication. This study also offered a complex perspective that proved how AI-generated calligraphy both enriches and challenges existing esthetic norms. Finally, the study provided key findings, proposing future directions that aim to deepen our understanding of AI-generated art in the global social mosaic, ultimately illuminating the dynamic interactions between social expression, creativity, and technology.

## 2. Historical evolution of calligraphy esthetics

### 2.1. Esthetic traditions in Chinese calligraphy

Chinese calligraphy has a long history, and its esthetics have also evolved with the historical context, humanistic environment, ideological movements, and other social factors of each era, demonstrating unique philosophical concepts and artistic values belonging to that era. Four prominent styles—valuing imagery (尚象, *shangxiang*), valuing charm (尚韵, *shangyun*), valuing rules (尚法, *shangfa*), and valuing meaning (尚意, *shangyi*)—have significantly shaped its development.

#### 2.1.1. Shangxiang esthetics

*Shangxiang* is an important component of the *Book of Changes*. It presents an abstract and symbolic Oracle Bone Inscriptions, which are highly generalized after people observe the nature, heaven, and earth. These textual symbols are often associated with nature, totems, and worship. These textual symbols are often associated with nature, totems, and worship. In the hands of ancient calligraphers, they spread in twists and turns, vividly imitating the surrounding world and meeting the needs of daily functions, such as the characters for mountain (山, *shan*) and water (水, *shui*). Each individual has their own unique personality, which showcases the simple and beautiful artistic quality of the original text.<sup>12</sup>

#### 2.1.2. Shangyun esthetics

Zhuangzi philosophy is centered around the concept of “the way of heaven is in accordance with nature,” and was deeply influenced by the Wei and Jin dynasties. They believed that art should conform to the laws of nature, and all objective expressions should be natural. Subjectivity should conform to objectivity and return to nature.<sup>13</sup> Therefore, in Wang Xizhi's masterpiece *Lan Ting Xu* (Preface to the Poems Composed at the Orchid Pavilion), we can see a slowing rhythm, a consistent use of the center tip of the

brush, and an expansive sense of three-dimensional space in writing. The Wei and Jin people exuded a calm, elegant, and transcendent aura on paper.<sup>14</sup>

### 2.1.3. Shangfa esthetics

The creation of regular script in the Tang Dynasty reached its historical peak. The norms and rules of calligraphy in the Tang Dynasty were closely related to the imperial examinations of that era. For each character, the strokes should be well-proportioned, and the structural center of gravity should be stable. At the same time, to avoid monotony, one needs to adjust the tight-loose relationship between the strokes and the space to achieve visual balance. Ouyang Xun's *Thirty-six Methods of Character Structure* was a masterpiece in this regard. It is also a highly influential work in the history of Chinese calligraphy. Even today, it remains a standard textbook for the writing of Chinese characters.

### 2.1.4. Shangyi esthetics

In the Song Dynasty, the literati became the primary force on the political stage. The social concept was open-minded, and the social environment was relaxed. Artists had unprecedented creative space and ideological patterns. The free-spirited and unrestrained style of running and cursive scripts became the core of creation at that time. Su Shi's calligraphy featured a flat-shaped character with slightly thicker vertical strokes, while Huang Tingjian's calligraphy had a character shape leaning toward an irregular trapezoid, with long and slanted strokes. These two artists commented on each other's character shapes as "a toad crushed by a stone" and "a dead snake hanging on a tree" respectively. Evidently, the calligraphy style emphasizing artistic conception can actually be regarded as a form of self-entertainment among the literati group. With the primary purpose of expressing personal sentiments and unique temperaments, it was a breakthrough from the rigid traditions. This also made the Northern Song Dynasty a glorious and remarkable era in the history of Chinese calligraphy.<sup>15</sup>

After that, during the Yuan and Ming Dynasties, people started to imitate the calligraphers of the Jin Dynasty again. The renowned calligrapher Zhao Mengfu advocated changing the form of characters in line with the times while following the traditional brushwork of the ancients. This became the golden rule for calligraphy learners in later generations.

These esthetic characteristics may seem independent of one another, but they are interrelated. In each dynasty, several works transcended the norms of their time. Take Yan Zhenqing in the Tang Dynasty as an example. His

regular script was highly regulated and strict in form, while his running and cursive scripts, shaped by his integrity and straightforwardness, more vividly manifested the feature of "advocating artistic conception." These traditional esthetics, through generations of inheritance, have highlighted the adaptability and expressiveness of Chinese calligraphy, enabling it to remain relevant across different cultural epochs.

## 2.2. Cultural connotations of calligraphy

Chinese calligraphy is deeply intertwined with the philosophies of Confucianism, Daoism, and Buddhism, serving as a cultural symbol and moral tool.

### 2.2.1. Confucian influence

Confucianism emphasizes internal self-reflection and self-moral restraint. It applies "rites" to regulate the behavior of each individual and endeavors to build a harmonious, balanced, and stable society. When this philosophical concept is integrated with art, the act of writing itself becomes a method to cultivate the mind, calm the spirit, and enhance inner stability, as fully demonstrated in the structural esthetic of regular script in the Tang Dynasty, an era that emphasized regulations. Therefore, for calligraphy, Confucianism aligns with the teachings of self-discipline and moral cultivation. As a result, both regular script and Confucianism were esteemed as the official orthodox criteria for judgment.

### 2.2.2. Daoist influence

Daoism regards the way of nature and following the laws of the origin and existence of all things as its educational purpose. Artists who believe in Laozi and Zhuangzi believe that pure nature, free from the constraints of experience and knowledge, and based solely on intuition and self-perception, is the beauty of creation. Therefore, a masterpiece often features smooth and completely unrestrained lines. At the same time, it can showcase strength and momentum through variations in the thickness, weight, and length of the strokes, and express the emotions and temperament of the author. For example, Zhang Xu or Huai Su, whose chaotic and harmonious lines are highly ornamental, and even the content of their works is dramatic. For example, the work *Belly Pain Postscript* is a mocking note written during abdominal pain, which demonstrates the principle of "inaction" in Daoism.<sup>16</sup>

### 2.2.3. Buddhist influence

Stele-inscribed Buddhist scriptures and Zen calligraphy ink marks are particularly important parts of Buddhist culture, and they have also played a huge role in the inheritance and promotion of calligraphy. Today, three

thousand years after the development of calligraphy, copying, and even copying from memory the *Preface to the Great Tang Sanzang Holy Teachings* (a calligraphy copybook that describes the journey of Tripitaka Master in obtaining Buddhist scriptures and related information about the scriptures) compiled by Monk Huairan, which took 24 years to complete with a reward of a thousand gold for each character of Wang Xizhi's calligraphy, is still a necessary path for all calligraphy learners. This was the lifelong wish of Emperor Li Shimin of the Tang Dynasty, leaving an invaluable treasure for future generations. Throughout the entire process of copying and memorizing, the writer naturally completes a spiritual practice and endows the written words with a religious sense of sanctity.

In the Song Dynasty, scholars were fond of discussing the profound principles of Zen. They tried to integrate these Buddhist concepts into the artistic conception of their poems, lyrics, and calligraphy. Su Shi and Huang Tingjian mentioned above were examples. They believed that one must first understand the methods, but not be constrained by them. Only by mastering and transcending traditional methods can one achieve an unrestrained artistic conception and essence. This ideology had a significant impact on the formation of the *shangyi* calligraphy style in the Song Dynasty, and the high-level integration of art and spirit was vividly demonstrated here.<sup>17</sup>

Calligraphy writing as a shared sign means that, more than its deep roots, it functions as a shared symbol, demonstrating good rules and creative style. The saying “the style is the person” sums up how calligraphy writing shows the writer's way of being and good traits. Furthermore, words on buildings and plates, written in calligraphy, remain as lasting signs of shared and past identity, boosting their place as a group work.

These shared meanings lift Chinese calligraphy writing beyond just an art form—it functions as a lively path for deep thinking, good teaching, and shared memory.

### 2.3. Evolution of calligraphic tools and techniques

The evolution of Chinese calligraphy reflects a rich interplay between esthetic core tenets and technological breakthroughs in artistic tools and techniques. Traditional calligraphy relies on four fundamental elements: (i) Brushes (毛笔, *maobi*), which is made by mixing various animal hairs, and due to differences in elasticity, it can create lines with strikingly different visual effects when writing; (ii) Ink (墨, *mo*), when the ink stick is mixed and ground with water on the inkstone, it can form ink with uneven color. Combined with the structure of the brush, it can produce multiple ink colors, commonly known as “ink divided into five colors”; (iii) Specialized paper (纸, *zhi*), can be divided

into raw Xuan paper, treated Xuan paper, and semi-treated Xuan paper according to their water absorption differences. It is used as a key writing medium to cooperate with the writer in creating unique personal works; (iv) The inkstone (砚, *yan*), during the grinding process of the ink ingot, the flatness of the inkstone directly affects the final effect of ink color. Each of these tools contributes distinctively to the calligrapher's artistic expression, with their individual qualities and interactions determining the visual and tactile outcome of the artwork, thus highlighting how the technical components of calligraphy are as important as the esthetic principles guiding the artist's hand.

The techniques of Chinese calligraphy consist of three parts: Brushwork, character structure, and composition. Brushwork is closely related to the birth and development of the writing brush. Starting from the rough craftsmanship in the early days, such as “the bamboo tube” brush, to the refined and delicate ones later, such as “the mouse whisker” brush, the evolution of the writing brush directly led to a transformation in the appearance of characters. From the rough and less variable strokes of oracle bone inscriptions, bronze inscriptions, and seal scripts, it shifted to the delicate and smooth running and cursive scripts. Character structure refers to the center of gravity, appearance, and spatial proportion relationships of the character. “Calculating the black based on the white” is a very important technique point, and its variations depend on differences in eras and creators. For example, compared with the character forms in the Song Dynasty, those in the Tang Dynasty had more regular structures, with relatively compact and well-proportioned spatial blank arrangements. In contrast, the character forms in the Song Dynasty were more flexible and changeable, and the blank space designs were also diverse. The same goes for the method of composition. From the evenly spaced arrangements in the early years to the more spontaneous changes in later generations, composition, through generations of inheritance and innovation, has become more characteristic of the times, more vivid, and more mature. This highlights an important concept: the equipment and technical elements of calligraphy are just as important as the esthetic principles that guide artists' creations.

The area of new calligraphy writing is known for its fusion of traditional methods and innovative high-tech ideas, where computer technology and AI significantly transform the art-making process. Computer systems and smart programs, such as Stable Diffusion (SD), have made calligraphy writing more accessible to people by introducing new ways for anyone to try and new ways to be creative, pushing against traditional art rules and expanding the scope of creative work.

Today's calligraphy writing groups now incorporate new methods that integrate traditional techniques with different supplies, computer spaces, and ideas from diverse sources, showing a global art world that values both old traditions and new ideas. These growing steps utilize computers to create layered, hands-on experiences that view calligraphy writing in new ways, introducing elements of moving pictures, computer-based changes, and computer-generated art while still adhering to the deep thinking and beauty rules of the traditional art style.

By combining traditional methods and new ideas, new calligraphy writing navigates a complex field that respects group customs while still changing with new computer tools, maintaining its strong impact and life in a growingly connected and online world.

### 3. Modern esthetic psychology and changes in Stable Diffusion calligraphy

#### 3.1. Trends in modern esthetic psychology

The advent of digital technology has significantly transformed esthetic psychology, continuously enhancing the diversity and personalization of art appreciation. Audiences who have grown up in the modern art environment, apart from seeking “pleasure to the ears and eyes” from artworks, also expect to perceive certain implications within the esthetic images, that is, “pleasure to the heart and mind.” Ultimately, the audience's aim is to achieve “pleasure to the will and spirit,” meaning reaching a psychological resonance with their life ideals, generating a sense of pleasure, and attaining satisfaction in the spiritual realm.<sup>18</sup> Therefore, in the process of seeking satisfaction for both psychological feelings and the soul, people pursue a more unique taste in artworks. They take experiences that align with their personal preferences and cultural backgrounds as the criteria for appreciation.<sup>19</sup> This transformation is vividly demonstrated in the integration of AI into art. Works generated by AI also offer new forms of expression that challenge traditional esthetics.<sup>20</sup>

What follows is a dazzling diversity of changes in the field of art appreciation, as well as a continuously increasing degree of personalization. In the context of globalization, people's self-awareness has gradually awakened, and their identification with their own subjectivity has also increased. Everyone is striving for unique, customized experiences that resonate with their personal preferences and cultural backgrounds.<sup>19</sup> This shift is evident in the process of integrating AI into art. The AI-generated works not only provide a new form of expression that challenges traditional esthetics but also fully satisfy people's sense of self-creation.<sup>20</sup> As viewers engage with the generative process—not just the final image—they become attuned

to the rhythm, timing, and flow of virtual brushstrokes, which mirrors the embodied discipline of traditional practice.<sup>21</sup> This participatory perception may, in turn, guide audiences toward a deeper understanding of Confucian self-cultivation and Daoist embodying the Dao through the reactivation of the “writing–perceiving” continuum, offering a more integrated cultural experience.<sup>22</sup>

In the digital environment we live in today, various cutting-edge technologies converge and blend together, opening a new door to art for humanity. The visual impact and emotional resonance people experience through interactive and immersive experiences are unprecedented. AI technology, based on this environment, has created works that are more vibrant and artistically appealing. These works not only attract audiences from multiple sensory levels but also form deeper emotional connections with viewers.<sup>23</sup> For example, AI-generated calligraphy can add unpredictable random variations to the work based on the algorithm's random parameters. The lines formed during the variation process naturally become some abstract elements in the work. Their existence transcends conventional understanding, bringing a new interpretation to traditional forms, triggering diverse and rich emotional responses.<sup>5</sup>

#### 3.2. Mechanism of esthetic reshaping via Stable Diffusion calligraphy

The SD model is a specialized algorithm that does not blindly create chaos. By fine-tuning various strictly set parameters, the model completes stroke writing based on the preset probability distribution in the model library, encompassing the initiation, execution, and conclusion of strokes, transitions, the interconnection between strokes, as well as the variation in stroke thickness, line direction, speed, ink density, and other highly professional writing techniques. This controllable randomness generates and drives the entire process of innovative design, playing a pivotal role in reshaping Chinese calligraphy esthetics.

##### 3.2.1. Role of randomness in altering traditional norms

Traditional Chinese calligraphy follows numerous established norms, emphasizing balance, harmony, inheritance, intentionality, and creativity. However, through the integration of random elements into the SD model, traditional calligraphy has been deconstructed and reconstructed in terms of stroke shape, ink distribution, and structural composition, with even the stroke order changing. As a result, AI-generated calligraphy works are distinctly different from the traditional ones, retaining the traditional charm of pen and ink while challenging traditional writing norms, creating new dynamics and

visual tension. This new visual order's beauty not only challenges traditional norms but also stimulates creativity due to its deliberate randomness, giving birth to a unique style that deviates from traditional forms, expanding the esthetic vision of this art in a comprehensive and deeper way.<sup>5</sup>

These images illustrate how algorithmic randomness can enhance the visual appeal and emotional resonance of calligraphic works.

Figure 1, composed of three works (uses the Zhao Mengfu running regular script font library as a diffusion model), exhibits significant variation in the initial stroke formation—specifically at the entry points—employing exposed tip (露锋, *lufeng*), concealed tip (藏锋, *cangfeng*), and side-tip (侧锋, *cefeng*) writing. These variations appear deliberately crafted, suggesting intentional esthetic diversity. Furthermore, overlapping strokes generate unpredictable ink blending effects, creating a fluid and naturalistic quality that evokes the Daoist principle of non-action (无为, *wuwei*)—spontaneity arising from effortless execution.

Figure 2 illustrates three-character phrases, using the same model as Figure 1. Beyond subtle variations in stroke turns, these works embody essential characteristics of running script (行书, *xingshu*), including dynamic contrasts in density, rhythm, and tonal weight—alternating between light and heavy, fast and slow. The compositions maintain structural stability while featuring rich gradations in ink tone, effectively conveying the rhythmic flow of calligraphy and reflecting the calm, meditative state required in traditional practice. These qualities make the works particularly engaging for contemporary audiences.

The four images in Figure 3 were generated using the same model as those in Figures 1 and 2, but with different diffusion parameter values during training, resulting in a more successful integration of traditional brushwork with AI-generated elements. In this series, certain strokes exhibit

a “wet ink” visual effect, with clearly layered ink tonality and an ample use of “intentional emptiness” (deliberately designed blank areas in calligraphy). Visually, the works suggest steady, powerful brush movements—controlled and well-balanced—conveying strength without chaos, and dynamism without loss of restraint. The final works thus achieve both strong visual impact and profound emotional resonance. Collectively, these cases demonstrate that algorithmic randomness, when thoughtfully integrated, not only enriches the esthetic experience of calligraphy but also opens new pathways for cognitive and emotional engagement with this traditional art form.

However, not all applications of randomness in AI-generated calligraphy achieve the desired esthetic effect. The following examples (Figures 4 and 5) illustrate some of the challenges and limitations inherent in integrating



Figure 2. Three generated calligraphic phrases using the same diffusion model as Figure 1, illustrating dynamic rhythm and tonal variation characteristic of running script (行书, *xingshu*). Image generated by the authors using Stable Diffusion.



Figure 1. Three generated calligraphic renderings of the Chinese character of purple (紫, *zi*), produced using a diffusion model fine-tuned on the Zhao Mengfu running-regular script dataset, illustrating variations in stroke initiation styles. Image generated by the authors using Stable Diffusion.



Figure 3. Four generated calligraphic images using the same diffusion model as Figures 1 and 2, showing wet-ink effects, layered tonality, and deliberate intentional emptiness. Image generated by the authors using Stable Diffusion.

algorithmic randomness into traditional calligraphic practice.

Figure 4, which utilizes the Deng Shiru seal script font library as a diffusion model, consists of two series. The work on the left exhibits excessive ink diffusion, with strokes and structure lacking coherence. For instance, a sudden flying white (intentional ink breakage; 飞白, *feibai*) appears in the downward-left stroke (撇, *pie*) at the lower-left corner, seemingly arbitrary rather than expressive. On the right, the right half of the composition suffers from erroneous strokes generated by random diffusion during model training, resulting in a chaotic structure and inconsistent brushwork. As a result, viewers struggle to visually interpret the artist's or system's creative intent. This overemphasis on randomness ultimately undermines the work's esthetic appeal and emotional resonance.

Figure 5, which uses the Jin Nong clerical script font library as a diffusion model, presents a set of works produced when the SD model did not undergo sufficient diffusion during training. As shown, these characters exhibit features typical of printed typefaces—such as uniform neatness, consistent stroke thickness, and geometric rigidity. Some strokes display rough, hasty dragging or sweeping marks at the beginning or end due to random noise, while others consist only of outline contours without authentic ink texture. These visual inconsistencies create an emotional disconnect from the intended artistic qualities, such



Figure 4. Two series generated with a Deng Shiru seal script diffusion model, showing incoherent strokes and chaotic structure due to excessive and random ink diffusion. Image generated by the authors using Stable Diffusion.



Figure 5. Calligraphic images generated with a Jin Nong clerical script diffusion model with limited training diffusion, exhibiting uniform, rigid strokes and minimal ink texture. Image generated by the authors using Stable Diffusion.

as “organic variation,” “simplicity,” “stability,” “fluidity,” “rich ink gradation,” or “five-colors-of-ink” (a traditional esthetic referring to subtle tonal shifts). This chaotic visual experience fails to elicit the intended cognitive and emotional responses, risks cultural misinterpretation, and raises deeper questions about how randomness can be meaningfully aligned with visual coherence to meet audiences’ affective and perceptual expectations.

Collectively, these cases underscore the necessity of balancing algorithmic randomness and established esthetic principles in AI-assisted calligraphy. Only through such calibration can harmonious, expressive, and culturally resonant works be achieved.

Consider the following examples (Figures 6 and 7). These figures demonstrate how randomness can transform calligraphy into abstract art, even if the characters themselves are meaningless. The two works in Figure 6 demonstrate how chaotic ink diffusion and unconventional stroke patterns create a visually striking and evocative abstract composition. This result is derived from random variations applied to a model of Huang Tingjian’s running regular script, which exhibits certain stroke and character shape characteristics, despite lacking clear semantic meaning. Similarly, the series in Figure 7 showcases two works that originate from random variations applied to Jin Nong’s clerical script model. Variations in stroke thickness and ink



Figure 6. Two works generated using a Huang Tingjian running-regular script diffusion model under random variations, producing abstract compositions with chaotic ink diffusion and unconventional stroke patterns. Image generated by the authors using Stable Diffusion.



Figure 7. Two works generated with a Jin Nong clerical script diffusion model under random variations, yielding stylized abstract forms with varied stroke thickness and ink distribution. Image generated by the authors using Stable Diffusion.

distribution lead to esthetically pleasing, stylized abstract forms that possess a sense of convention, even though they do not convey specific messages. These examples highlight how randomness expands the boundaries of traditional calligraphy into the realm of abstract art, offering new esthetic experiences that challenge established standards.

### 3.2.2. Tools facilitating calligraphy randomness

Advanced generative control tools, such as ControlNet and specialized small models, have significantly enhanced the controllability and creativity of random elements in AI-generated calligraphy. ControlNet enables precise adjustment of similarity between generated outputs and reference images, allowing fine-grained guidance over stroke direction, structural composition, and stylistic features. This empowers artists to introduce algorithmically driven variations while preserving the fundamental conventions of calligraphy, thereby achieving an effect of “unexpectedness within control.”<sup>24</sup> Furthermore, small models trained on diverse datasets of historical calligraphic works can integrate visual vocabularies across different schools and dynastic periods, generating subtle and novel formal variations. This algorithmically induced “unintentional creativity” not only enriches the artistic expressiveness of AI-generated calligraphy but also offers viewers a new pathway to re-engage with core esthetic principles of traditional practice—such as “the brush follows emotion” (笔随气动, *bisuiqidong*) and “vital rhythm and dynamic life” (气韵生动, *qiyunshengdong*). By contrasting the machine’s “atypical brush intent” with the human writer’s “emotional rhythm,” these generated works can, paradoxically, highlight the cultural distinctiveness of traditional calligraphy. Such technical integration thus imbues models like SD with deeper artistic exploratory potential, expanding the horizon of creative possibilities for calligraphy in the digital age.<sup>25</sup>

### 3.2.3. Mathematical representation of esthetic randomness

The process of generating esthetically pleasing randomness in SD calligraphy can be represented mathematically, as shown in Equation (1).

$$C = \sum_{i=1}^n (P_i \cdot R_i) + \epsilon \quad (1)$$

where:

- $C_{output}$ : Final calligraphy composition
- $P_i$ : Predefined esthetic parameters (e.g., stroke weight, ink density)
- $R_i$ : Random variables introduced by SD algorithms
- $\epsilon$ : Controlled noise for stylistic variation.

This formula encapsulates the interplay between traditional constraints ( $P_i$ ) and modern randomness ( $R_i$ ) in creating innovative calligraphy, reflecting the integration of predefined esthetic parameters—such as stroke weight and ink density—with algorithmically generated variations. It signifies not a replacement of calligraphy’s cultural core—the embodied practice of writing—but rather a technological relearning and reconfiguration of its visual characteristics.

### 3.3. Comparative analysis with traditional calligraphy

To comprehensively explore the cognitive and emotional dimensions of calligraphy, comparative analysis revealed the different characteristics between traditional and AI-generated methods (SD). Traditional calligraphy attracts audiences through precise technical expression, exquisite artistic techniques, and persistent adherence to established esthetic principles, evoking emotional responses rooted in cultural and philosophical depth, such as openness and reverence. In contrast, SD calligraphy introduces a paradigm shift by utilizing randomness and technological innovation, creating a more dynamic audience experience characterized by unpredictability, curiosity, and intellectual stimulation.

The provided figures (Figures 1-3) are exemplary cases of visual innovation in AI-generated calligraphy within the context of a paradigm shift. Traditional calligraphy emphasizes precision in brushwork and ink application, as well as the intentionality behind writing, often evoking esthetic responses, such as “elegance,” “leisurely spontaneity,” and “composure.” In contrast, these AI-generated works expand the perceptual dimensions of calligraphic art through algorithmically driven unpredictability and formal novelty. The three works in Figure 1 employ fluid ink diffusion effects that break conventional stroke logic, prompting viewers to interpret the works from non-traditional perspectives, thereby stimulating cognitive engagement and esthetic reflection at a rational level. The three works in Figure 2 create contrasts of density and openness—hallmarks of running script—through variations in ink intensity and rhythmic tension between the upper and lower characters, engaging viewers in a more direct and visceral manner. Figure 3 seamlessly integrates the brush techniques of running script, including variations in pressure, speed, and rhythm during execution, with abstract visual elements, resulting in visually striking artworks that challenge established boundaries of traditional calligraphy and may evoke a range of complex emotional responses—from excitement and curiosity to momentary confusion.

The visual characteristics generated by random mechanisms in these examples, such as the blending of ink colors and variations in brush strokes, not only demonstrate the innovative potential of AI in the formal expression of calligraphy but also make it an effective visual carrier for the cross-cultural transmission of traditional calligraphy. For Western audiences, these works can serve as a “perceptual entry point” into the esthetics of calligraphy, allowing them to initially experience its visual impact while gradually building an understanding of deeper cultural cores (such as the flow of vital energy and concepts like “intention precedes the brush”), thereby laying a cognitive foundation for further in-depth exploration of the embodied practices and philosophical implications of traditional calligraphy.<sup>22</sup>

### 3.4. Implications for calligraphy education and appreciation

Traditional calligraphy invites people to engage in contemplative appreciation of the inheritance of techniques and the historical background of calligraphy. In contrast, AI-generated (SD) calligraphy prompts the audience to actively interpret and engage with artworks that break conventional expectations, potentially evoking a wider range of emotional responses, from excitement and curiosity to momentary confusion. This comparative examination highlights the dynamic character of artistic perception, demonstrating how technological intervention can fundamentally transform the cognitive and emotional interaction between people and artistic expression, blurring the boundaries between human creativity and algorithm-generated works.

The figures provided (Figures 6 and 7) serve as examples of this paradigm shift. Traditional calligraphy places emphasis on the lineage of renowned masters and the inheritance of techniques. People develop a sense of admiration and emotional connection toward calligraphy works due to the familiarity they evoke and the exceptional craftsmanship demonstrated. In contrast, the AI-generated calligraphy in these figures introduces elements of unpredictability and curiosity that can transform the art form into abstract art. The two images in Figure 6 create visually striking and expressive abstract compositions through chaotic ink diffusion, embodying stylistic characteristics of Huang Tingjian, despite lacking clear semantic content. The two works in Figure 7 form esthetically pleasing clerical script forms in the style of Jin Nong, shaped by variations in stroke thickness and ink distribution, even though they convey no specific message. These examples illustrate how randomness can extend the boundaries of traditional calligraphy into the realm of abstract art, offering novel esthetic experiences that challenge established artistic standards.

These cases clearly demonstrate that the randomness in AI-generated calligraphy can expand the boundaries of traditional calligraphy from “text-based art” into the domain of “abstract visual art.” On one hand, it breaks down traditional barriers in cross-cultural communication by offering non-linguistic visual impact; on the other hand, it provocatively challenges the long-held assumption that “calligraphy must be legible.” However, it must be emphasized that the core value of such abstraction lies not in replacement but in serving as a cognitive bridge for cross-cultural transmission.<sup>25</sup> To prevent cultural superficiality due to semantic loss, these AI-generated works should be accompanied by contextual interpretation—such as embedded videos of master calligraphers’ brush movements, or explanations of techniques like flying white as natural outcomes of embodied writing practices. This enables audiences to move beyond formal appreciation toward a deeper understanding of the bodily and philosophical foundations of traditional calligraphy.<sup>26</sup>

## 4. Interactive effects of randomness, culture, and cognition

### 4.1. Cultural connotations as bridges

Audience familiarity with traditional calligraphic esthetics serves as a vital bridge in the acceptance of SD-generated calligraphy. Traditional esthetics, deeply rooted in cultural and philosophical traditions, provide a framework through which viewers interpret and appreciate new forms of artistic expression.<sup>27</sup> For example, the visual elements in the calligraphy works generated by SD, such as the connection of aura, delicate changes in starting and ending strokes, and transitions, as well as changes in ink color, all connect with the creative principles of Wang Xizhi’s *Lan Ting Xu* and other classic works, facilitating audience engagement and acceptance.<sup>5</sup>

Randomness in SD-generated calligraphy introduces novel visual elements that evoke diverse cognitive and emotional responses. For instance, the random blending of ink creates unexpected patterns, ranging from thick to light, dry to wet, tight to loose, stimulating the audience’s curiosity and imagination in exploring the inner philosophy or emotions of the work, prompting them to interpret it in a unique way. This process aligns with research on visual complexity in calligraphy, which suggests that moderate complexity and novelty can enhance audience engagement in the appreciation of art.<sup>28</sup> In SD calligraphy works, the random diffusion of ink color creates a moderately complex visual object for the viewer, including ink color, brushwork, lines, and abstract shapes. This ensures that the viewer does not feel bored due to the esthetic object being too easy to understand, nor does it experience cognitive

pressure due to being too far from their esthetic experience. They are also greatly attracted by the differences between these works and those in their experience, and are eager to explore the details and creative motivations that make these works distinct from the past.

However, Figures 4 and 5 serve as examples demonstrating the limitations that arise when the randomness of algorithms fails to harmonize well with traditional esthetic principles. In Figure 4, the random diffusion based on the Deng Shiru clerical script font leads to excessive ink blending, disrupting the compositional balance and creating a chaotic visual effect. This not only fails to evoke curiosity and imagination among viewers but also imposes a sense of oppression, hindering their understanding of the work. The disordered diffusion of ink breaks the structural integrity of the characters, failing to reflect the classical elegance and rhythmic quality characteristic of Deng Shiru's calligraphy. Similarly, Figure 5, generated from the Jin Nong clerical script font, suffers from uneven or insufficient diffusion during its creation, leading to an imbalance in artistic expression and chaotic ink distribution. The strokes appear disjointed and mechanically rigid, lacking the texture and intentional artistry found in Jin Nong's original calligraphy. The features, such as abrupt fractures, the arbitrary use of flying white effects, and strokes that are merely outlines without any ink texture, further exacerbate the visual confusion. These elements do not enhance the expressiveness of the work but rather weaken its esthetic coherence and emotional resonance. These cases illustrate that the overuse or improper application of randomness can damage the formal integrity and cultural readability of AI-generated calligraphy works. They highlight the importance of integrating algorithmic transformations with profound esthetic values—not to stifle innovation, but to ensure that randomness serves the expressive intent. The ultimate goal is to create works that are not only visually harmonious but also meaningful and engaging on cultural and emotional levels.

## 4.2. Impact on calligraphy heritage and innovation

The introduction of randomness into SD-generated calligraphy has broadened engagement with the art form, making it more accessible to a wide range of audiences. Once regarded as an exclusive discipline that demanded years of dedication, calligraphy has been revitalized through AI, allowing greater involvement and interest.<sup>29</sup>

### 4.2.1. Democratizing calligraphy appreciation

With the help of AI-based tools, people who have not received deep training in traditional calligraphy can still explore its core esthetic elements. Randomness plays a key

role in this influence, as people can adjust the parameters of ControlNet to create visually striking works with rich ink color variations, clear styles, and distinct personalities based on their basic graphics, catering to the requirements of modern esthetics—combining multiple cultural experiences with high-tech means, and efficiently and conveniently expressing their independence and uniqueness. The vibrant and bold visual impact in the work is formed by the strong contrast of stroke thickness and the irregular blending of ink, directly and clearly expressing the inner language of those social people who crave breakthroughs and pursue freedom, especially popular among young audiences.

### 4.2.2. Bidirectional empowerment and creative cultivation

Randomness has proven essential in attracting younger audiences and inspiring artistic exploration. Platforms, such as SD, allow users to reconfigure the spatial structure of traditional calligraphic strokes in novel ways, while simultaneously engaging with the contemporary esthetic of art-technology integration.<sup>1</sup> As calligraphy becomes increasingly embedded in digital media and modern design, it is not enough to merely leverage “low-threshold visual creation” to spark initial interest. Instead, there is a critical need to guide young creators from AI-generated experimentation toward embodied traditional practice. Initiatives, such as “AI generation + hand copying” workshops—where youth first generate compositional drafts using AI and then manually replicate them with brush and ink—enable a tactile understanding of stroke dynamics, ink control, and cultural resonance. This hybrid approach not only exemplifies the deep integration of tradition and innovation but also reflects the joy new generations derive from cultural synthesis. While experiencing the timeless allure of this artistic heritage, they actively incorporate personal creativity, thereby strengthening their sense of cultural belonging and identity.<sup>6</sup>

Moreover, AI technologies can support the digital preservation of calligraphy's embodied practices. By capturing master calligraphers' brush movement data and constructing a relational database linking technique, emotional expression, and cultural context—a brush technique (笔法, *bifa*)-emotion-culture framework—AI systems gain more culturally grounded training data, while invaluable records of traditional craftsmanship are preserved for future inheritance (传承, *chuancheng*). This establishes a virtuous cycle of “tradition nourishing technology, technology enriching tradition”—a model of true bidirectional empowerment.

Consequently, SD-generated calligraphy both preserves traditional artistic values and stimulates new modes of

creativity, helping the art form remain relevant in a shifting cultural landscape. By welcoming fresh audiences and expanding its scope, calligraphy continues to evolve as an expression of both art and cultural identity.

### 4.3. Cultural influences on perception

Examining the cultural contexts of AI-based (SD) calligraphy highlights the multi-level intersection of perception, interpretation, and emotional engagement, with different interpretations between Eastern and Western cultures. In most parts of the East, especially in China, calligraphy is associated with philosophical systems, such as Confucianism, Daoism, and Buddhism. These philosophical systems guide the audience on how to interpret the randomness of the algorithm through concepts, such as non-action.<sup>30</sup> This approach integrates technological innovation with philosophical resonance, resulting in profound cultural experiences. Meanwhile, Western audiences tend to adopt a more formalistic perspective, focusing on visual expression, creativity, esthetic exploration, and creative process, which provide them with a unique cognitive and emotional resonance for such works.<sup>31</sup> The unpredictability of SD calligraphy poses a challenge to the traditional artistic style and pattern recognition, prompting the Oriental audience to seek coordination and unity between novel changes and established traditions, while the Western audience is more inclined to accept the new dimensions and concepts brought by multiculturalism and interpret the works with an open and rational attitude.<sup>28</sup> Although there are cultural differences between the East and the West, due to the common esthetic principles of human beings' innate visual attraction, such as balance, unity, rhythm, and proportion, the vague sense of cultural differences in SD calligraphy works is more conducive to the establishment of cross-cultural ties. As a mixed art form, SD calligraphy has become a dynamic medium, combining classic cultural heritage with modern technology-driven innovation methods, which can especially arouse the resonance of the younger generation who seek the value and significance connection between the past and the present.<sup>29,31</sup>

### 4.4. Case studies and examples

AI-produced (SD) calligraphy showcased in exhibitions like "Eternal Ink" and in series such as "Random Harmony" underscores the profound potential of harnessing technological innovation to transcend cultural divides through artistic means. These pioneering examples demonstrate how randomness paired with digital intervention can yield shared esthetic experiences that both respect established artistic principles and push creative limits. By fusing precise calligraphic techniques

with spontaneous AI-driven variations, artists like Li Wei create compositions that resonate widely—drawing Eastern viewers who appreciate philosophical and historical authenticity, as well as Western viewers attracted by novel esthetics and inventive experimentation.

In SD calligraphy, which integrates cutting-edge technology and traditional art, randomness, cultural influence, and cognitive factors interact to create a multidimensional innovation environment with great vitality for the development of art and educational progress, and provide great possibilities for the further development of traditional art in the future. Cross-cultural cooperation in this cultural environment has great potential. It can enable artists, educators, and scholars from different fields to collaborate, absorb inspiration from each other, and jointly explore new creative paths beyond the limitations of traditional art.<sup>32</sup> However, potential problems, such as cultural misunderstandings and technical barriers between these fields, must also be addressed.<sup>33</sup> Strengthening education courses and using multilingual interpretation tools can mitigate the negative impact of these challenges and significantly enhance people's in-depth understanding of the cultural significance behind SD calligraphy by providing key background information.<sup>34</sup> If these obstacles can be overcome, this high-tech, innovative medium can become a powerful bridge for international cultural exchanges, and create a good opportunity to expand new horizons of art, promote multicultural exchanges and understanding, and promote the prosperity and development of global culture and art through the imaginative integration of art and technology.<sup>35</sup>

## 5. Cross-cultural esthetics and cognitive emotion

### 5.1. A comparative framework of Eastern and Western perceptions of Stable Diffusion calligraphy esthetics

#### 5.1.1. Divergent philosophical foundations and esthetic criteria

When appreciating calligraphy works generated by SD, Eastern and Western audiences employ fundamentally distinct conceptual frameworks rooted in divergent philosophical traditions—differences that shape not only esthetic evaluation, but also the perceived roles of AI in cultural transmission, artistic innovation, and intercultural dialogue. In the East, calligraphy is understood as a spiritual practice grounded in Confucian, Daoist, and Buddhist thought, where the principle of the unity of heaven and man (天人合一, *tianrenheyi*)—derived from Zhuangzi—posits that the artist's inner state, cultivated through lifelong discipline of self-cultivation, manifests directly in

brushwork.<sup>10</sup> Each stroke embodies vital energy, rhythm, and moral integrity, forming a holistic convergence of body, mind, and nature. Formal elements, such as flying white and intentional emptiness (留白, *liubai*), are interpreted as expressions of breath, emotion, and cosmic resonance.

In contrast, we initially hypothesized that Western audiences—shaped by Greco rational traditions emphasizing logic, individual agency, and conceptual inquiry<sup>36</sup>—would be more inclined to embrace AI-generated art, particularly works produced through algorithmic and mathematical processes. We expected them to focus on formal innovation, visual novelty, and critical reflections on technology, analyzing several elements, such as line direction, texture, and spatial composition, and probing the artist's intentions regarding futurity or human-machine relations.

However, survey findings reveal that this assumption does not fully hold when applied to an art form deeply rooted in philosophical and cultural traditions, such as calligraphy. Western attitudes toward AI in this context are notably divided: only 40% supports its use in calligraphy education, 40% remain skeptical, and 20% outright oppose it. This suggests that Western audiences do not automatically accept AI's artistic legitimacy simply due to its technological basis. On the contrary, precisely due to their strong orientation toward logical reasoning, they place greater emphasis on the motivation, cultural provenance, and mechanisms of meaning-making behind the work.<sup>36</sup> For instance, in esthetic evaluations, only 30% of English-language respondents mentioned core Eastern concepts, such as “harmony” or “balance.” Instead, 70% emphasized “innovation,” “experimentation,” and “conceptual depth,” indicating a tendency to engage with unfamiliar artistic expressions through critical and intellectual frameworks.

In contrast, respondents from East and Southeast Asia—including students from China, Japan, Korea, and Malaysia—demonstrated a foundational understanding of calligraphy's visual language, with as many as 80% identifying “harmony” and “balance” as key esthetic criteria.<sup>24</sup> This divergence highlights a significant opportunity: While AI-generated calligraphy challenges traditional brush-based practice, it also opens a new pathway for cross-cultural dialogue. By visually manifesting features that are difficult to achieve manually—such as flying white, dry brush (枯笔, *kubi*), and dynamic ink diffusion—AI works can serve as perceptual catalysts. When combined with multimodal interpretive strategies—such as annotated explanations, VR simulations of brush movement, or guided narratives on Daoist and Confucian aesthetics<sup>10</sup>—these approaches have been shown to enhance intercultural comprehension.<sup>38</sup> In this way, AI-generated

calligraphy can help Western audiences move beyond purely technical critique and gradually access the deeper dimensions of calligraphic practice, including breath rhythm, intentional emptiness, and the philosophical ideal of the unity of heaven and human.<sup>10</sup> Thus, far from being merely a technological experiment, AI-generated calligraphy emerges as a meaningful bridge for fostering deeper cross-cultural understanding of Eastern visual aesthetics and cultural essence.

### 5.1.2. Generational shifts within Eastern audiences

A significant intergenerational divide exists within Eastern societies. Older practitioners, trained in classical calligraphy, emphasize the embodied discipline of brushwork—where breath control, wrist pressure, and rhythmic movement form an inseparable triad of bodily perception, expression, and cultural transmission. They view algorithmic randomness as bypassing decades of somatic training, reducing creation to a mechanistic process from data to parameters, and ultimately the output, and question whether AI-generated works can truly possess spirit resonance (神韵, *shenyun*) or transmit cultural essence.<sup>1</sup>

However, younger generations—digital natives—interpret randomness not as a deficiency but as expressive expansion. Our survey shows that 90% of East and Southeast Asian students believe that AI can help “popularize calligraphy among youth,” and 80% support its integration into art curricula, provided it complements traditional practice. Notably, 65% find the “dynamic ink diffusion” and “unpredictable line flow” of SD-generated works esthetically compelling. More importantly, 60% reported that their initial fascination with AI-generated styles led them to study classical techniques, such as “traces of leaking roof” brushwork (屋漏痕, *wulouhen*) or the philosophical roots of self-cultivation. This suggests that AI functions not as a replacement for tradition, but as a cultural on-ramp—a digital invitation to return to heritage.

### 5.1.3. Cultural interpretive challenges for Western audiences

When encountering AI-generated calligraphy, such as that produced by SD, Western audiences often struggle to interpret its esthetic and cultural meanings due to limited familiarity with Chinese calligraphic traditions.<sup>24</sup> This challenge arises not only from differing esthetic sensibilities but also from fundamental contrasts in writing systems. In the Western alphabetic tradition, writing emphasizes clarity and visual continuity, where gaps or broken strokes are typically seen as mistakes. As one English-speaking respondent admitted: “I saw the gaps as errors, not as intentional emptiness.”<sup>XX(YYY)</sup> Effects like flying white—

the deliberate ink breakage that creates dynamic tension between presence and absence—are thus often misread as technical flaws rather than expressive choices rooted in Daoist and artistic principles.<sup>10</sup>

Yet AI-generated calligraphy disrupts these assumptions. Because AI does not follow human motor constraints, it produces unexpected visual forms—such as fragmented lines, uneven ink diffusion, and stark contrasts between fullness and void—that challenge conventional expectations. These features, difficult to achieve in traditional practice, become a cognitive turning point: Viewers begin to recognize that incompleteness may be intentional. When paired with embedded cultural strategies—such as multilingual annotations, VR simulations of brush movement, or narrative guides that explain intentional emptiness as breath and mental space<sup>38</sup>—AI works can serve as gateways to Eastern esthetics. Rather than erasing cultural depth, AI, when contextualized, enables a deeper cross-cultural understanding by inviting audiences to reconsider the meaning of form, silence, and emptiness.<sup>22</sup>

## 5.2. Opportunities and challenges in cross-cultural communication

The appreciation of AI-generated calligraphy, particularly works produced through models like SD, cannot be divorced from the deep cultural and philosophical frameworks that underpin traditional Chinese calligraphy. In Chinese Calligraphy as a Cultural Practice, calligraphy is far more than a visual art form—it is a disciplined bodily practice rooted in Confucian ideals of self-cultivation and the Daoist principle of the unity of heaven and man.<sup>26</sup> Each stroke embodies vital energy, rhythm, and moral integrity, emerging from a somatic triad of breath, wrist control, and mental focus. This embodied understanding shapes how Eastern audiences interpret even algorithmically generated works: features, such as flying white or intentional emptiness, are not merely formal elements, but expressions of emotional dynamics and spiritual resonance.<sup>25</sup>

However, when these works are encountered by Western audiences—whose esthetic frameworks are often shaped by Greco rational traditions emphasizing conceptual innovation and visual novelty—such symbolic layers risk being overlooked. Without contextual grounding, the rhythmic complexity and intentional emptiness in calligraphy may be misread as randomness or compositional deficiency, especially in cross-cultural exhibitions.<sup>25</sup> This interpretive gap underscores the need for culturally sensitive presentation strategies that do not assume shared hermeneutic frameworks.

In response, emerging scholarship suggests that AI-generated calligraphy may serve not as a replacement for

tradition, but as a bridge to it. Digital heritage technologies, including AI, can function as tools for cultural continuity, particularly among younger generations who may lack direct exposure to classical training.<sup>22</sup> Their research demonstrates that AI-generated styles can spark curiosity and serve as a “digital on-ramp” to traditional practice—aligning with survey findings that indicate 60% of students who engaged with SD-generated calligraphy later sought to study classical techniques (Table 1).

Yet, the integration of AI into cultural education remains contested. While Eastern audiences generally support its use in pedagogy—provided it complements, rather than replaces, embodied practice—Western respondents exhibit greater skepticism, with 40% expressing doubt and 20% outright opposition to its role in art education (Table 1). This divergence echoes some research’s original insight:

**Table 1. Comparative analysis of Eastern and Western perceptions of Stable Diffusion calligraphy esthetics**

| Aspect                          | Eastern perspective                                                                                                                                                                          | Western perspective                                                                                                                                                                                                                                                                                   |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Philosophical foundation        | Rooted in the unity of heaven and man (天人合一, <i>tianrenheyi</i> ), Confucian harmony, and self-cultivation (修身, <i>xiushen</i> ) <sup>10</sup>                                               | Guided by Greco rational ideals: logic, individual agency, and conceptual inquiry <sup>36</sup>                                                                                                                                                                                                       |
| Artistic evaluation criteria    | Values embodied practice, brush rhythm, and symbolic forms (e.g., flying white [飞白, <i>feibai</i> ], intentional emptiness [留白, <i>liubai</i> ]) as expressions of inner state <sup>36</sup> | Emphasizes visual novelty, formal innovation, and conceptual depth (e.g., tech critique, futurity); 70% <sup>a</sup> of English-speaking respondents highlighted these over traditional esthetics. <sup>36</sup> Only 30% <sup>a</sup> recognized “harmony” or “balance” as core values <sup>24</sup> |
| Interpretation of randomness    | Older: sees as bypassing somatic training; questions vital energy (气, <i>qi</i> )<br>Youth: views as expressive expansion <sup>22</sup>                                                      | Often perceives randomness as a form of artistic experimentation and freedom <sup>36</sup>                                                                                                                                                                                                            |
| Role of technology              | Must serve tradition; AI should complement human intention and cultural continuity <sup>1</sup>                                                                                              | Embraced as a tool for breakthroughs and boundary-pushing <sup>36</sup>                                                                                                                                                                                                                               |
| Preferred application domain    | Art education (90%) <sup>a</sup> , cultural transmission (80%) <sup>a</sup>                                                                                                                  | Commercial design (70%) <sup>a</sup> , conceptual art (60%) <sup>a</sup>                                                                                                                                                                                                                              |
| Attitude toward AI in education | Supportive (80%) <sup>a</sup> , but insists on integration with traditional practice                                                                                                         | Mixed: 40% <sup>a</sup> support, 40% <sup>a</sup> skeptical, 20% <sup>a</sup> oppose                                                                                                                                                                                                                  |

Note: <sup>a</sup>Data sources: Author-conducted surveys (2025), *n*=144 (105 students from East and Southeast Asia, 39 Western-background respondents).

Abbreviation: AI: Artificial intelligence.

calligraphy's value lies not only in its visual outcome, but in the lifelong discipline and moral cultivation it demands.<sup>21</sup> Any effort to globalize AI-generated calligraphy must therefore move beyond technological spectacle and engage seriously with these philosophical undercurrents.

To foster genuine cross-cultural appreciation, institutions should develop multilingual interpretive frameworks that explain not just what is seen, but why it matters. Even small interventions—such as curated annotation cards explaining flying white as a deliberate expression of breath and emotional tension—can significantly enhance viewer comprehension.<sup>25</sup> When combined with immersive digital platforms and pedagogical models that position AI as a dialogic partner rather than an autonomous creator, these strategies can help transform AI-generated calligraphy from a novelty into a meaningful site of intercultural dialogue.<sup>22</sup>

### 5.3. Esthetic perception and the esthetic dilemma of randomness

The introduction of algorithmic randomness in SD calligraphy brings both opportunities and challenges. Although it fosters novel esthetic expressions, its acceptance varies significantly between Eastern and Western audiences, as shown in Figures 4–7.

From an Eastern perspective—especially within a Confucian–Daoist framework—calligraphy should embody balance, rhythm, and spiritual resonance.<sup>21</sup> In Figure 4, excessive ink diffusion disrupts the harmony of the composition, failing to evoke the Daoist principle of non-action. It does not exhibit natural spontaneity but instead appears chaotic and aimless, preventing viewers from connecting with the work's philosophical depth. Similarly, Figure 5 displays rigid strokes that lack vitality and inconsistency in brushwork. Techniques, such as flying white, that symbolize breath and emotional tension in traditional practice seem arbitrary here, weakening the work's esthetic coherence and emotional resonance.

In contrast, Figures 6 and 7 demonstrate how controlled randomness can generate attractive abstract forms. Despite lacking semantic content, these works display strong formal beauty—dynamic compositions, visual rhythms, and texture contrasts—that appeal to audiences from diverse cultural backgrounds. Specifically, Figure 6 originates from the random diffusion of Huang Tingjian's regular script font library, creating a free-spirited yet symbolically meaningful abstract form; whereas Figure 7 is based on Jin Nong's clerical script font library, forming highly esthetically pleasing abstract forms through random variations. This suggests that abstract esthetics may serve as a universal introductory pathway, especially for Western

audiences who prioritize visual innovation over symbolic meaning.<sup>25</sup>

Notably, generational differences further complicate acceptance. Older generations—regardless of Eastern or Western—often associate genuine calligraphy with physical skill of essence, energy, and spirit (精气神, *jingqishen*) and may find algorithmic randomness lacks intent. Younger generations, more accustomed to digital media and hybrid cultural forms, are more likely to view AI-generated works as legitimate creative expressions.<sup>22</sup> This generational gap highlights the necessity for differentiated dissemination strategies. Therefore, the key challenge lies not in eliminating randomness but in calibrating it—combining algorithmic variation with culturally resonant esthetic principles to create innovative and meaningful calligraphic works.

### 5.4. Dissemination strategies in bridging the esthetic gap

To address the core challenges outlined in Section 5.3—namely, uncontrolled randomness leading to potential cultural misinterpretations and purely abstract forms lacking depth—cross-cultural communication strategies must integrate cultural roots with technological innovation.

First, contextual interpretation is crucial. As seen in Figures 4 and 5, algorithmic effects, such as ink diffusion or flying white without cultural context support, are easily misunderstood. Therefore, multilingual interpretative materials, such as annotated digital exhibitions or augmented reality-driven “brushstroke analysis,” which explain how specific visual features correspond to philosophical concepts, such as non-action and vital rhythm (气韵, *qiyun*),<sup>6,37</sup> are necessary. For example, the random diffusion results of Deng Shiru's clerical script model in Figure 4 and Jin Nong's clerical script model in Figure 5 require detailed cultural background introductions for correct interpretation. This transforms randomness from a technical product into a culturally readable expression. Second, tiered educational design can address generational differences. Projects targeting older audiences should emphasize continuity between AI works and traditional principles by juxtaposing masterpieces with SD outputs. For younger audiences, game-like VR experiences can enable them to co-create calligraphy with AI, understanding the integration of tradition and innovation in practice.<sup>38</sup> Third, curatorial positioning is essential. In global exhibitions, SD calligraphy should be presented not merely as Chinese art but as a form of dialogue—a conversation between human intention and algorithmic possibilities. Placing it within contemporary art or digital humanities contexts (rather than classical art

spaces) aligns with Western esthetic expectations while preserving cultural depth.<sup>25</sup> For instance, [Figures 6 and 7](#) could be showcased in modern art exhibitions to highlight their abstract esthetics and cross-cultural potential.

Finally, collaborative creation platforms—such as AI-assisted calligraphy workshops or cross-cultural commentary forums—can promote mutual understanding. Inviting global participants to generate, annotate, and discuss SD calligraphy can transform passive viewing into active cross-cultural dialogue.<sup>39</sup> Participants might use Zhao Mengfu, Huang Tingjian's regular script font libraries, and Jin Nong's clerical script font library for creation, sharing their interpretations and feelings about these works.

These strategies do not aim to unify esthetic responses but rather to construct structured pathways for cross-cultural meaning-making. Through these methods, we can gain a deeper understanding and appreciation for the unique charm of AI-generated calligraphy, promoting its spread and acceptance worldwide.

## 6. Conclusion and outlook

### 6.1. Research summary

This study explored the transformative impact of randomness in SD-generated calligraphy on traditional esthetics, cognitive-emotional responses, and cross-cultural communication. Although randomness poses a challenge to the existing writing norms, writing guidelines, intentionality, and creative sources in Chinese calligraphy, it has emerged as a powerful driver of esthetic innovation and a means to engage a new generation of global audiences. By integrating randomness, SD-generated calligraphy not only stimulates curiosity, creativity, and emotional resonance but also redefines the modes of dissemination and popularization of calligraphic culture in contemporary society. Furthermore, it highlights the core value of traditional calligraphy as a culturally grounded art form, rooted in embodied practice, building a bridge between classical Chinese philosophy and contemporary digital art.<sup>5,23]</sup>

In addition, the calligraphy generated by SD has become a cultural channel, integrating the foundation of Eastern philosophy with the praise of Western rational abstraction and innovative thinking, thus shortening the distance between cross-cultural audiences. It can make calligraphy more accessible to the public, which not only expands interest in traditional calligraphy among the young digital generation but also enables a global audience to quickly access this ancient and difficult calligraphy art through the network platform, and carry out convenient and effective

artistic creation.<sup>1,31</sup> In this way, SD calligraphy not only protects this world cultural heritage that has been inherited for thousands of years but also breaks down language and cultural barriers and redefines its significance and value in the modern social environment.

### 6.2. Implications for calligraphy preservation and innovation

The combination of AI and random elements in calligraphy undoubtedly opens up a new path for safeguarding and reimagining this ancient art. While respecting the basic esthetic traditions of calligraphy, AI cleverly integrates and expands calligraphy with modern technology, striving to quickly adapt to modern and future global audiences. By combining the rich concepts and exquisite techniques of classic calligraphy with advanced technology, this method not only upholds the continuity of millennium culture but also opens up an unprecedented path for innovative experimentation in this traditional art. Intentionally integrating randomness and AI-based methods into the creative process can prevent calligraphy from stagnating or remaining in museums. Through the massive learning provided by AI, a continuous stream of creative inspiration can help creators reshape calligraphy as a dynamic and constantly developing art practice that combines modern high-tech social processes and resonates with audiences from different generations and cultural backgrounds. This forward-looking strategy has promoted the popularization of calligraphy, a small art form. Through the interactive digital platform that stimulates creativity and critical thinking, different cultural groups can find and participate in the appreciation and creation of calligraphy, ensuring that calligraphy remains important and vibrant in the rapidly digitalized global environment. The integration of AI and algorithmic randomness in calligraphic creation opens a new pathway for the contemporary preservation and innovative development of this ancient art. By respecting its fundamental esthetic principles and philosophical depth, this approach leverages AI technologies to transcend traditional media and creative constraints, enabling calligraphy to better respond to modern esthetic expectations and cross-cultural communication challenges. Rather than replacing humanistic values with technology, this fusion controls randomness to inspire new artistic possibilities—allowing calligraphy to maintain cultural continuity while gaining adaptive vitality for the future.

This practice can be understood as a co-evolution between the carrier and cultural essence. Here, AI-generated calligraphy serves as the carrier, facilitating formal exploration and expanded dissemination, while the embodied practices, symbolic imagery, and spiritual

dimensions of traditional calligraphy constitute the irreducible cultural essence. On one hand, algorithmically driven randomness helps break free from formulaic reproduction and prevents the art from becoming static or museum-bound. On the other hand, only when grounded in this cultural essence can technological innovation remain meaningful, avoiding superficial or fragmented visual pastiche. It is precisely within this dynamic tension that calligraphy transforms from passive preservation into active cultural regeneration.

This forward-looking collaborative strategy not only promotes broader participation in calligraphic creation but also fosters engagement through interactive digital platforms that stimulate creativity and critical thinking. It enables audiences across generations and cultural backgrounds to participate in both the appreciation and production of calligraphy, allowing younger users to experience its contemporary vitality through technological innovation, while helping cross-cultural audiences gradually grasp its deeper esthetic and philosophical values through visual reexpression and contextual interpretation. In this process, technology becomes more than a tool; it acts as a bridge connecting tradition with the present, as well as the local with the global communities. Ultimately, this approach ensures that calligraphy, within the rapidly evolving digital landscape, maintains the core significance of its cultural essence while continuously renewing its artistic vitality, realizing the living transmission and dynamic evolution of cultural heritage.

### 6.3. Future research directions

Although relevant research and creation have made continuous progress, a significant gap remains in the comprehensive understanding of how SD-generated calligraphy affects cross-cultural esthetics and the emotional response mechanism. To address these deficiencies, future research should adopt empirical methods and combine cutting-edge technologies to provide solutions.

#### 6.3.1. Empirical cross-cultural studies

At present, the cognition of SD calligraphy from a cross-cultural perspective is largely derived from qualitative data. To obtain a more comprehensive view, follow-up research should combine quantitative techniques, such as eye tracking, emotion analysis, questionnaire surveys, and comparative discussions, to explore how audiences with different cultural backgrounds can participate in and interpret calligraphy works generated by SD.<sup>18</sup> In addition, a comparative study of intergenerational differences in a specific cultural environment will also provide more in-depth insights.<sup>27</sup>

#### 6.3.2. Esthetic measurement methods

Researchers also urgently need to establish a strong measurement framework to measure the impact of randomness in SD calligraphy on cognition and emotion. Even an in-depth study of the observation results of brain activity during the process of esthetic experience in the field of neuroscience may reveal key information on how randomness shapes perception and emotional response.<sup>10,23</sup>

#### 6.3.3. Expanding the Stable Diffusion model's capacity

The future improvement of the SD model should focus on fine customization, allowing users to control randomness by specifying parameters. The extended model adopts the style details and cultural elements of traditional calligraphy as the basic standard. It should not only strengthen the connection between the SD model and historical art forms, but also strive to achieve a new interpretation of art.<sup>5</sup> In addition, integrating multimodal features, such as interactive components or auditory elements, can deepen user participation and enhance the emotional and esthetic effects of SD-based calligraphy.

Through in-depth exploration of these research directions, researchers will rapidly strengthen the integration mechanism of high-tech and traditional art in the future, while deepening our understanding and closely integrating it with education, creation, and display, and promote it rapidly, so as to ensure Chinese calligraphy continues its esthetic value and innovative vitality for thousands of years from a global perspective.

### 6.4. Practical applications and recommendations

In an era of global multicultural exchange, ensuring that Chinese calligraphy maintains its cultural significance and continues to evolve on the world stage requires a multidimensional strategy that integrates technological innovation, educational development, and cross-cultural collaboration. By systematically incorporating AI-generated calligraphy into art and cultural studies curricula, this traditional art form can be made more accessible and relevant to contemporary learners. Simultaneously, the development of interactive digital platforms—equipped with intuitive tools for creation, simulation, and feedback—can lower barriers to artistic participation, enabling broader public engagement beyond specialized training. Organizing dynamic cultural exhibitions and public programs that vividly illustrate the interplay between traditional techniques and technological advancement allows calligraphy to transcend geographical and cultural boundaries, reasserting its vitality as a living art form in the digital age.

In educational practice, a dual-track approach is crucial to balance technological integration with cultural continuity. On one hand, AI tools can be leveraged to spark interest, provide stylistic exploration, and support creative experimentation, particularly among younger audiences. On the other hand, mandatory traditional calligraphy practice—such as regular hand-copying exercises—must remain a core component of learning, reinforcing the embodied skills of brush control, rhythm, and meditative focus that define the art's cultural essence. This helps prevent the misconception that AI can fully replace manual practice. Furthermore, in public exhibitions or digital displays featuring AI-generated calligraphy, clear labeling should be used to distinguish between AI-generated works and hand-crafted works. Such transparency supports accurate cultural interpretation and enables audiences to better understand the distinct values and processes behind each mode of creation.

At a systemic level, these initiatives should contribute to the development of an inclusive and sustainable cultural ecosystem. This ecosystem should prioritize immersive, participatory experiences that invite collaboration among artists, students, and enthusiasts across age groups, professions, and cultural backgrounds. By encouraging interdisciplinary perspectives—from design and technology to philosophy and aesthetics—Chinese calligraphy can be reinterpreted and reconstructed as a dynamic medium of global artistic expression. Rather than remaining a niche tradition, it can become a bridge between diverse esthetic and technological domains, fostering mutual understanding, creative innovation, and intercultural dialogue. In this way, calligraphy not only preserves its cultural depth but also evolves as a vital, responsive, and universally engaging art form in the digital era.

### 6.5. Final thoughts

Encouraging broad participation in the fields of art, academia, and technology is crucial for reshaping calligraphy for future generations. When people from diverse backgrounds—whether computer scientists, traditional artists, or cultural historians—come together to explore and reinterpret this millennia-old art form, they open up new creative dimensions for its future evolution and provide a broader space for experimentation. This innovative collaboration fosters fresh insights: Technological tools expand the possibilities of esthetic expression, while ancient traditional techniques impart profound depth and cultural heritage to the works. By creating an intercultural and geographical environment that allows creative collaboration to flourish, calligraphy can evolve from its long-standing roots into a vibrant,

boundary-breaking global art form of expression. This innovative model not only effectively bridges cultural differences but also propels calligraphy art toward unexpected innovative fields, ultimately connecting traditional culture with modern technology. It fosters a comprehensive and deep mutual understanding while also generating profound esthetic interactions.

When randomness was integrated into the generation of Chinese calligraphy, a hallmark moment in the development of this art form, it brought about a monumental transformation. Traditional calligraphy upholds precise and rigorous techniques, representing a spiritual connection between philosophical culture and the emotions of the creator. However, the randomly integrated digital elements broke all existing barriers, expanding the innovative horizons of the digital elements with infinite possibilities. Each work created with the help of machine learning and algorithmic programs was endowed with a surprise, highlighting a new interactive relationship between the artist, tools, esthetic concepts, and the works created. This dual adherence to traditional inheritance and innovative experimentation has injected fresh blood into Chinese calligraphy, keeping it vibrant and significant in an era of rapid technological development. More importantly, it has created a platform for different cultures and disciplines to intersect, share, and develop together, thereby enriching the entire global art field. By embracing this new direction of artistic creation, practitioners and scholars have not only consolidated the profound and long-standing historical heritage of calligraphy but also promoted its continuous innovation through keen insight and bold action. This ensures that calligraphy, an artistic tradition that has endured for thousands of years, will maintain strong vitality and inspiration in future generations, helping it stride toward a more diverse, inclusive, and innovative global art field.

### Acknowledgements

None.

### Funding

This work was supported by the 2023 General Project of Shanghai Educational Science Research C2023262 Theoretical Construction and Exploratory Application Research of Educational Metauniverse. This study is a part of the 2023 Shanghai Key Curriculum Construction project on “Chinese Calligraphy Art.”

### Conflict of interest

The authors declare that they have no competing interests.

## Author contributions

Conceptualization: Kai Wang

Investigation: Kai Wang

Methodology: Kai Wang

Visualization: Kai Wang

Writing–original draft: Kai Wang

Writing–review & editing: All authors

## Ethics approval and consent to participate

This study was conducted in compliance with ethical standards for educational research. As it involved anonymous surveys with adult participants and no sensitive data, formal ethics approval was not required under our institutional guidelines. Informed consent was obtained from all participants before data collection.

## Consent for publication

All participants provided informed consent for participation in the study. The data were collected and reported in an anonymous manner, with no individual identifiers used or published. Therefore, additional consent for publication is not required.

## Availability of data

The datasets generated during the current study are available on reasonable request from the corresponding author.

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