Evaluation and Analysis of White Space in Wu Guanzhong's Chinese Paintings

ZHENBAO FAN, KANG ZHANG AND XIANJUN SAM ZHENG

ABSTRACT

This article reports on a recent study that examines the effect of white space on perception of Chinese paintings. The authors investigate whether white space in Chinese paintings is not simply a blank background space but rather meaningful for aesthetic perception. Applying a computational saliency model to analyze the influence of white space on viewers' visual information processing, the authors conducted an eye-tracking experiment. As a case study, they analyzed paintings by a well-known artist, Wu Guanzhong, and collected users' subjective aesthetic ratings. Their results show that white space is not just a silent background: It is intentionally designed to convey certain information and has a significant effect on viewers' aesthetic experience.

Leaving white space is a typical artistic method in Chinese painting, white being the color of the Chinese rice paper employed rather than that of a pigment. Art critics have argued that the space so used is not just meaningless empty background but is intentionally left or designed as empty to benefit the overall composition of the painting. Such white space mostly depicts vast, formless, endless, ever-changing natural phenomena such as skies, clouds, rivers, lakes, etc., or simply empty spaces not indicating any specific phenomenon. The artists intentionally leave space for viewers' imagination and anticipation as a philosophical approach. Most classical and representational Chinese ink paintings with white space were created by feudal-era scholar-official literati painters. Many well-known masterpieces use white spaces skillfully, e.g. Fan Kuan's *Travelers among Mountains and Streams*, Guo

Xi's *Early Spring*, Li Tang's *Windy Pines among a Myriad Valleys* or Xia Gui's *In Clear View of Streams and Mountains* [1].

Art experts, however, find it difficult to prove that white space is not just empty and meaningless space but intentionally designed to convey useful information and contribute to the painting's composition in an objective and quantitative way. To discover the meaning of white space in Chinese ink paintings, we chose paintings by Wu Guanzhong (1919–2010) [2], an acclaimed contemporary master well known for his skillful use of white space in his paintings. Wu studied both western oil painting and Chinese ink painting and mastered both styles. We selected Wu's Chinese ink paintings with white spaces, and oil paintings sharing the same or similar scenes or objects, to perform a comparative study.

The study is implemented in three steps (see Fig. 1). First, we applied a computational saliency model to calculate salient regions [3], as detailed in the Computing Salient Regions section. Second, an eye-tracking experiment was performed to collect viewers' eye movement data. Third, selected paintings were rated on four aesthetic dimensions based on AttrakDiff [4–6], reported in the Experiments section. We next review related work, followed by our conclusions.
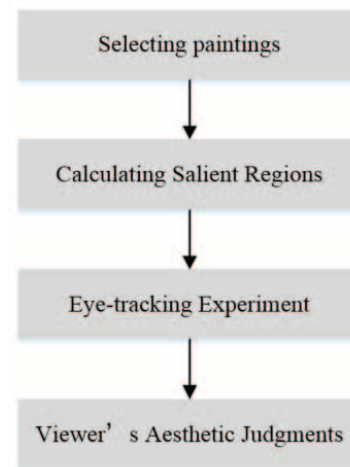

Fig. 1. Procedure for the study. (© Kang Zhang)

COMPUTING SALIENT REGIONS

Human control of visual attention involves both a bottom-up strategy, which is stimulus driven and rapid, and a top-down strategy, which is slower and volition controlled [7].

ZhenBao Fan (researcher), Department of Computer Science, University of Texas at Dallas, Richardson, TX 75082-3021, U.S.A. Email: zbfan@utdallas.edu.

Kang Zhang (educator), Department of Computer Science, University of Texas at Dallas, Richardson, TX 75082-3021, U.S.A. Email: kzhang@utdallas.edu. Web: www.utd.edu/~kzhang.

XianJun Sam Zheng (researcher), Department of Psychology, Tsinghua University, Beijing 100084, China. Email: sam.zheng@gmail.com.

The two-step model of Nodine and Krupinski confirms that a person viewing a painting with a rapid scan can perceive its main points [8]. Viewers can perform a reliable aesthetic evaluation of a painting or website after several initial eye movements [9]. Based on these findings, we decided to focus on the first stage of visual attention, the bottom-up strategy, to study whether white space influences viewers' aesthetic experience.

If white space is not just a meaningless background but conveys certain information, it may attract viewers' attention. We therefore would like to determine how viewers' visual systems selectively process information when viewing a painting. The saliency model was inspired by the behavioral and neuronal architecture of the early primate visual system [10]. Image features such as color, luminance and orientation were combined into a single topographical saliency map and stimulated a dynamical neural network to select attended locations in order of decreasing saliency. The saliency toolbox, a Matlab implementation of Itti and Koch's saliency model [11], supports the calculation of the salient regions of any given painting. We use the saliency model with default parameters, i.e. the lowest center level at 3, the highest center level at 5, the smallest c-s delta at 3, the largest c-s delta at 4 and the saliency map level at 5.

We selected Wu's representative paintings and analyzed whether white spaces were included in the salient regions by calculating the saliency map in each painting. The results are shown in Figs 2 and 3, where the trajectory in each painting is marked by numbers representing the viewing sequence. A salient region of each ink painting contains at least a small amount of white space. In our experiment, if the white area occupies over 30% of a salient region, the salient region is considered to contain white space. As noted below, white spaces in these paintings are either bounded, such as walls (bounded by roofs and ground lines, etc.), snowy mountains (bounded by contour lines of hills), rivers (bounded by riverbanks) or terraces (bounded by field lines), etc., or unbounded, indicating sky or cloud above a scene or simply empty space.

In *Snow Mountain* (Fig. 2a), white space was used to depict snow covering the mountain. The results of the saliency model show that the attended regions were snows in the

Fig. 2. Calculated saliency result of (a) *Snow Mountain*, (b) *A Landscape with Houses*, (c) *Suzhou*, (d) *Water Field in Hills*, (e) *Tianfu Terrace*. (Source: Wu Guanzhong. Saliency maps © Kang Zhang.)

Fig. 3. Calculated saliency results of (a) *Twin Swallows*, (b) *Tiger Runs in Hangzhou*, (c) *Weeds on the Top of Wall*, (d) *Houses under the Yulong Mountain*. (Source: Wu Guanzhong. Saliency maps © Kang Zhang.)

distance represented by white space and green regions under the mountain. Thus, white space is included in a salient region in this painting.

A Landscape with Houses (Fig. 2b) and *Suzhou* (Fig. 2c) depict similar scenes and both use white space to represent a river. In *A Landscape with Houses*, white spaces are included in two of the top five salient regions. Similarly, in the painting *Suzhou*, the top seven salient regions include three with white spaces. White spaces are part of salient regions in these two paintings.

Water Field in Hills (Fig. 2d) and *Tianfu Terrace* (Fig. 2e) both use white spaces to represent water. The terrace is referred to as "Mirror Field" by locals. In *Water Field in Hills*, water under the mountain was represented by white space, like mirrors. What reflected imagery should appear on the water depends on viewers' imagination. By computing the salient model for *Tianfu Terrace*, we find two white spaces

in the top five attended regions: One is sky and the other is terrace. The sky near the mountain and water portrayed by curved lines are white spaces.

Walls were treated as white space in *Twin Swallows* (Fig. 3a), *Tiger Runs in Hangzhou* (Fig. 3b), *Weeds on the Top of Wall* (Fig. 3c) and *Houses under the Yulong Mountain* (Fig. 3d). The salient regions of some of these paintings include white spaces, while those in others do not. Except for the last one, white spaces in these pictures were very large. *Twin Swallows* is a well-known painting in which white spaces occupy a large area and looks quite simple in composition. But walls in this painting are not salient regions. In *Tiger Runs in Hangzhou* and *Weeds on the Top of Wall*, similarly, walls are not salient regions. However, edges of the walls in these pictures were all calculated as the attended regions. In contrast to these three paintings, white space in *Houses under the Yulong Mountain* is calculated as a salient region.

EXPERIMENTS

Participants

Twenty-two students majoring in science and engineering at Tianjin University, China, volunteered to participate in the experiment. All participants are Chinese and had normal or corrected-to-normal vision, without colorblindness. Although some of them may have heard of Wu Guanzhong, none were familiar with the artist's paintings. Of the 22 participants, four (two male and two female) participated in the eye-tracking experiment, while 18 others (ten male and eight female) participated in the comparison between oil and ink paintings and the rating experiment, described below.

Eye-Tracking Experiment

By analyzing the calculated results of the Saliency Model, we found that in some paintings white spaces do not become salient regions. The subjects were told to free-view the paintings without any given tasks, so that they would not know the purpose of this experiment. Paintings with large white spaces were selected to evaluate whether large white spaces would attract viewers' attention. These include five paintings downloaded from the Internet: *Spring Snow*, *A Landscape with Houses*, *Spring in Jiangnan*, *Twin Swallows* and *A Quadrangular Yard*. We used an eye-tracker (Tobii T60 XL eye-tracking system with a TFT screen resolution of 1920 × 1200 pixels) to record viewers' eye movements. The fixation duration was set at 60 ms and the fixation size at 10 pixels.

The heat maps clearly illustrate the attended regions in four paintings. In *Spring Snow* (Color Plate A, a), the top of the mountain was the most conspicuous attended region, and white spaces representing snows down the mountainside also attracted viewers' attention. In *A Quadrangular Yard* (Color Plate A, e), white space representing the ground was significantly attended. But not all results were as we expected. In *A Landscape with Houses* (Color Plate A, b), the river did not become an attended region. The edges of the river represented by white space, however, were all attended regions. For *Twin Swallows* (Color Plate A, d), viewers' fixations moved around the two big walls, which are bounded white spaces. The sky above is an unbounded white space. The edges of the walls became attended regions, shown more clearly on the trajectory diagram in Color Plate A, f. In *Spring in Jiangnan* (Color Plate A, c), the painter used white space to depict the river. The heat map indicates that the fishing boats in the river caught the viewers' attention, but the "white" river did not. The white spaces on top of *Spring in Jiangnan* and *Twin Swallows* are unbounded and did not become attended regions.

Questionnaire

We designed an aesthetic questionnaire composed of two parts. The participants were asked to state all objects they had seen in each painting and then give a score (1–7) on four rating criteria.

These rating criteria were selected from the AttrakDiff questionnaire, a scale developed by Hassenzahl et al. [12] to evaluate the attractiveness of a product or user interface de-

sign. AttrakDiff 1 contains 23 questions, using a scoring scale of one to seven. It calculates in three dimensions: Pragmatic Quality, Hedonic Quality and Appeal. Hassenzahl et al. [13] divide Hedonic Quality into two dimensions: Stimulation and Identity. This modified questionnaire is called AttrakDiff 2.

AttrakDiff focuses primarily on westerners. Liu et al. suggested that cultural differences between east and west would impact aesthetic ratings [14]. Easterners are more accustomed to combining objects and background as a whole, i.e. paying attention to relationships. In contrast, western people are used to separating objects from background and classifying objects [15]. Liu et al. [16] adapt the AttrakDiff 2 questionnaire for Chinese viewers, to include only three dimensions: Stimulation, Pragmatic Quality and Conformity. Because the AttrakDiff questionnaire was initially designed for evaluating interactive products, we found the dimensions of Pragmatic Quality and Conformity to be of little relevance to the aesthetic judgment of paintings.

We finally chose 4 dimensions: Attractiveness, Stimulation, Complexity and Identity. Complexity was added as a new dimension. We selected the most representative contrast in each dimension. These contrasts were, in order of the dimensions listed above: repelling vs. appealing, dull vs. captivating, complicated vs. simple and unrecognizable vs. recognizable. Participants were asked to enter a tick mark on a seven-point scale: for example, from "repelling" on the left end to "appealing" on the right end.

Oil and Ink Paintings

We selected seven pairs of ink and oil paintings in this experiment, depicting different scenes, e.g. river, wall, terrace, waterfall, etc. Similar scenes are portrayed in the ink paintings using white space and in the corresponding oil paintings. The selected ink paintings are *Spring in Jiangnan*, *The Tiantai Fall*, *Twin Swallows*, *Black Carps Harvest*, *Spring in Jiangnan* [No. 2], *Tianfu Terrace* and *Spring Snow*. The corresponding oil paintings are *Small Town in Jiangnan*, *Water Lane*, *Waterfall*, *Small Lane*, *Black Carps Harvest*, *Water Fields* and *Northland Scenery*.

Comparison and Rating

To quantify aesthetic judgment, we graded each painting by calculating an average score of the aforementioned four dimensions of Attractiveness, Simulation, Complexity and Identity. We used an iPad Mini 2 for displaying the paintings to the participants. Each participant performed the experiment individually. After receiving the experiment instructions, a participant was provided with the iPad for viewing paintings. Having viewed each painting, participants were asked to complete the questionnaire with aesthetic ratings of the paintings. This process repeated for a total of 14 paintings.

The average scores for seven oil and ink paintings are shown side by side in Fig. 4. In the dimension of Complexity, five of the seven ink paintings have higher scores than the corresponding oil paintings, implying that these paintings look simpler than the oil counterparts. In the dimension of Attractiveness, five of the seven ink paintings score higher
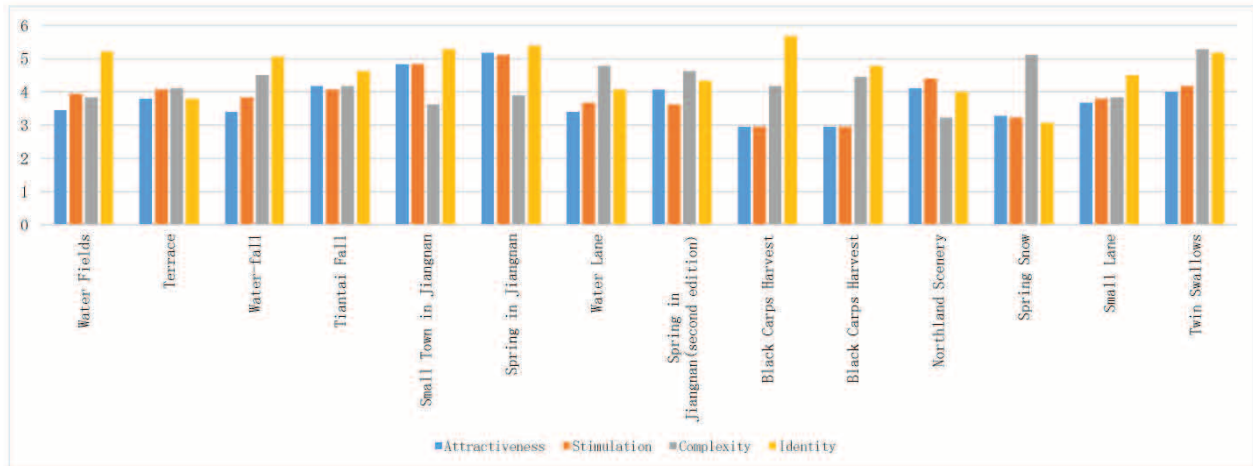
Fig. 4. Comparison of average scores between ink and oil paintings. (© Kang Zhang)

than the oil counterparts, indicating that they are considered more attractive. In *Black Carps Harvest*, the two types of paintings scored the same. In the dimension of Identity, four oil paintings are given higher scores, implying that they are more recognizable than the corresponding ink paintings. Two types of paintings have the same scores in *Black Carps Harvest*.

RELATED WORK

White Space in Chinese Paintings

Most studies about white space in Chinese paintings belong to the art field. Art reviewers believe that white spaces in Chinese paintings represent something significant [17], allowing viewers to fill in blank space with the imagination. This conception is consistent with the Taoist idea that empty space represents everything and nothing. In Taoism, empty space is considered the beginning of countless things; Laozi (founder of Taoism) said that "all things in the world come into being with a form, the form comes from the formless."

Wu Guanzhong's Paintings

Considered one of the greatest contemporary Chinese painters, Wu Guanzhong is particularly known for landscape paintings with large white spaces. "Wu's artistic style had a changing process from east to west, from oil to ink, from embodiment to abstract, just like from a known shore to an unknown shore," said Jia Fangzhou, an important art critic [18]. Wu's paintings have an emphasis on inheritance of traditional Chinese paintings and modern usage like abstraction [19]. Pan Tianshou, a great master of traditional Chinese paintings, who was also a teacher of Wu, said that "When I was creating an ink space with a brush on the paper, I was thinking about the white space in fact" [20]. The key principle Wu learned from his teacher is that "ink occupation in a painting should be strictly controlled, to express more with less." In the 1980s, Wu created ink paintings using white space frequently as an artistic method.

White Space Used in Other Areas

White space can also be used in the design of ads and architecture. Li et al. proposed that white space had infiltrated the spatial design of gardens, after analyzing expressions of white space in classical and modern Chinese gardens [21]. Pracejus et al. examined white space used in ad design and conducted several studies to explore brand meanings conveyed by white space in ads, concluding that white space represents prestige, market power, trustworthiness and leadership of the brand [22].

None of the aforementioned research empirically evaluated the effect and meaning of white space through viewers' eye movements.

CONCLUSIONS

What is encouraging about the results presented above is that white space does attract viewers' attention. This confirms the notion that white space was intentionally designed to represent something important in these scenes. In other words, white space contains information.

Furthermore, the size of a white space had an effect in determining its salience in attracting attention, but large white spaces in a painting may not attract viewers' attention, while the viewers' fixations would move around those spaces rather than on them. For example, in *Twin Swallows*, *Weeds on the Top of Wall*, *A Landscape with Houses* and *Suzhou*, regions around white spaces are all attended regions. The optimal size of white space for attraction of attention remains to be investigated in the future.

We are also encouraged by the finding that when different types of paintings share similar or the same scenes, ink paintings using white spaces are much simpler in composition, and the results are more appealing, as indicated by our experiments. Oil paintings are more intuitive than ink paintings because they are characterized by realism, while ink paintings in general are more abstract and minimalistic. In other words, the white spaces in ink paintings could provide viewers a simple yet aesthetic feeling but would potentially hinder viewers in recognizing objects portrayed by white spaces.

One limitation of our study is that the participants in the experiment were all native Chinese. Because different cultures and experiences can prompt different aesthetic judgments, we will extend our experiments to include participants with other cultural backgrounds.

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ZHENBAO FAN *is a PhD student in the Computer Science Department, University of Texas at Dallas. Her research interests include computational aesthetics and aesthetic computing.*

KANG ZHANG *is a professor in the Computer Science Department, University of Texas at Dallas, is an ACM Distinguished Speaker, and serves on the editorial boards of several journals. His research interests include generative art, aesthetic computing, visualization and visual languages.*

SAM ZHENG *is Research Director of Tsinghua Happiness Technology Lab (H+Lab) and also an adjunct professor of psychology at Tsinghua University, Beijing. His research interests include aesthetic perception and computing, user experience and AI, and human-machine relationships.*