Visual fixation patterns of artists and novices in abstract painting observations

Naoko Koide* Takatomi Kubo* Tomohiro Shibata* Kazushi Ikeda*
*Nara Institute of Science and Technology, Nara, Japan.
E-mail: naoko-ko@is.naist.jp Tel: +81-743-72-5982

***Abstract*—Artists have a specific evaluation of abstract paintings while art novices do that with difficulty. This difference is shown in eye fixation patterns, although the cause is not clear. To explain the difference in fixation patterns, we used one of the saliency maps of paintings which predict fixations well without prior knowledge such as a meaningful target. If artists had a deep knowledge of art, they attend less to the salient features than novices in observing abstract paintings. On the other hand, the fixation patterns possibly vary in visual tasks. Therefore we examined the effect of salient features in two tasks: free viewing and preference judgment. To evaluate this quantitatively, the correlation coefficient (CC) between fixation distribution and a saliency map was used. The CCs were compared between artists and novices for each task. We found that the CCs of artists were lower than those of novices in the free viewing task, but not in the preference judgment task. This implies that the artist's knowledge of observation paintings was appeared only in free viewing.**

I. Introduction

Artists easily form their own evaluations of paintings while art novices do so with difficulty. This difference is particularly apparent in the observation of abstract paintings and manifested in behavior, in particular eye fixation patterns. In the observation of paintings, a saccadic distance, which is the distance between one fixation point and the next, differs between artists and novices in three tasks: free viewing, memory and concentration on aesthetic details [1]. Especially in observation of abstract paintings to concentrate on aesthetic details, the distinct difference was shown although the cause of the difference was unclear. In a recent study by Vogt et al., similar results were shown in free viewing and memory of abstract paintings, but not of representational paintings; artists tended to have longer saccadic distances than novices [2]. Their study proposed that the difference between artists and novices in [1] was caused by pictorial conditions of paintings. Furthermore, eye fixation frequency within region of interest (ROI), which is an area of a recognizable object such as a human face, was compared between artists and novices. As a result, fixation frequency within the ROI of the artists was fewer than those of novices. They also suggested that artists tend to focus on pictorial features to a lesser extent. The ROI, however, was examined only in representational pictures and not in abstract paintings.

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To explain eye fixations in an image including both representational and abstract pictures, various human visual attention models have been proposed. Itti and Koch's saliency map, one of the most basic models, predicts fixation locations in free viewing without prior knowledge such as a recognizable object. This model was based on the behavior and the neuronal architecture of the early visual system and represents a salient value of a location in an input image for the system. The salient value is quantified by contrasts of each of following three features: color, intensity and orientation [3, 4]. We call these features "early visual features". In abstract paintings, there are no semantic objects. Artists, however, may have knowledge to detect meaningful targets in abstract paintings as in [2], while novices do not. In this case, novices possibly fixate more on early visual features according to the saliency map than artists in free viewing.

The effect of early visual features, however, may vary in visual tasks as in [1, 2]. A previous study also showed that the visual task given to an observer influences their eye movements [5]. Therefore we need to control for a task dependency. In this study, the preference judgment task was adopted as a control task to free viewing. The saliency map predicts well the fixation locations in free viewing [6]. In the preference judgment task, the observer's fixations may tend to attend less to the early visual features than in free viewing. In this case, the effect of the early visual features would not be different between artists and novices.

We also examined the similarity of fixation locations, whether the difference of the saliency effects were found or not. The fixation locations may be similar in each subject type; artists and novices. If the similarities were found only in each subject type, novices fixated on the early visual features while artist's fixations would attract another type of features.

To evaluate these quantitatively, fixation locations were modeled as a probability function called fixation distribution for each trial and subject. To examine the saliency-dependent fixations, we calculated the correlation coefficient (CC) between a saliency map and the fixation distribution in the observation of an abstract painting, which we shall call saliency effect Se. Respective Se values were compared for two factors: one for the subject type (artists/ novices) and the other for the task type (free viewing/ preference judgment). Then the similarities of fixated locations for each painting were quantified with the CC between pairs of fixation distributions, which we shall call similarity of fixation locations Sfl. The

Sfl values were also compared in each of the two factors.

II. Experiments

A. Participants

Five artists and six novices participated. The artists were recruited from art colleges; Kyoto University of Art & Design and Kyoto City University of Arts. Their art skills are certified by the entrance examinations of the art education institutions with *dessin* and color-composition skills. They had been in art for more than three years. Each of them had a different type of art specialty; Western-art (1), Japanese art (2), Sculpture (1), and Comic art (1). The average age of the artists was 20.4 $\pm$ 0.55 SD. The six novices had no profound knowledge of art. They were selected from three non-art departments: Computer science (2), Bioscience (2), and Humanities (2). The average age of the novices was 22.5 $\pm$ 1.38 SD. All the participants had normal or corrected-normal visual acuity and no color blindness. All the participants were selected so as to eliminate any differences in visual attention between the artists and the novices due to differences in general abilities excepting art skill or age.

B. Stimuli and apparatus

The experiment was divided into two experimental sessions: a free viewing session and a preference judgment session. Two unique sets of paintings, each of them consisting of 20 colored abstract paintings, were prepared for each experimental session to avoid any effect of the second observation. The 20 paintings in each painting set were made by the same 20 professional artists, who were selected from several major styles of art such as Orphism, Cercle et Carré, Futurism, Abstract expressionism, Art informel, Art Concret, Russian Avant-Garde, COBRA, and more contemporary art including digital art. All paintings had RGB color channels needed to generate saliency map and were trimmed to have square form. An eye tracking instrument, EyeLink II (SR Research) was located in front of the display on which one of all paintings was shown at a screen resolution of 1024$\times$768 pixels. The visual angle of the painting was approximately 22 degrees squared. All presentation was made with psychtoolbox in MATLAB (MathWorks). Subjects were seated at a distance of 60 cm from the screen inside a blackout curtain. The instrument recorded gaze locations from both eyes of the subject at a sampling rate of 500 Hz. Data output provided fixation duration times and coordinates, begin and end times of saccades, begin and end times of blinks. Fixation time was set at a minimum of 100 ms and saccade velocity was set at more than 22 degrees per a second [7].

C. Procedure

Gaze locations were recorded in two experimental sessions. One was in a free viewing session where the subject freely observed the 20 paintings of a painting set. The other was in a preference judgment session where the subject observed 20 paintings of the other painting set to answer whether he or she liked the paintings. All subjects were informed that their pupil sizes were recorded, in order for them to prevent controlling their gaze locations consciously. The task procedure for each experimental session is shown in (Fig.1). First, the subject was asked to fixate on the white cross in the middle of the display for one second. Next, one of the 20 paintings was displayed and the subject observed the painting for 20 seconds. In the free viewing session, after observing a painting, a new fixation period with the white cross was immediately started. In the preference judgment session, after observing a painting, the subject was asked to answer whether he or she liked the painting, did not like it, or was neutral about it with the left, right and up arrow keys respectively. Their gaze locations were recorded during the whole observation period. Drift correction was done before each trial and all recordings were conducted with the eyelink toolbox [8].

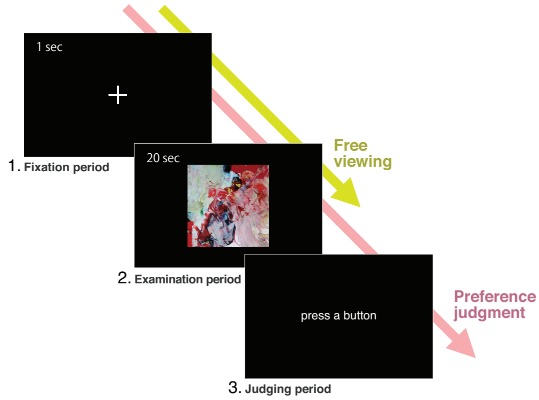

Fig. 1. Task procedure.

III. Analyses

To quantify the effect of bottom-up attention, a statistical similarity between subject fixation distribution and saliency map is measured for each subject and trial. Then the similarities between the artists were compared with those of the novices. In this study, fixation points, with the other gaze locations excluded, were used to evaluate similarity because fixation with a threshold of 100 ms was found to reflect visual attention and cognition in free viewing [9].

A. Distribution of fixation points

To compare fixation locations with a saliency map, fixation points for a given painting were modeled as a probability density function. We constructed a smooth distribution from the fixation points using a nonparametric density estimation method called the kernel density function (KDF). The KDF represents a distribution density of the fixation points within a range of a painting for each subject and trial by a sum of Gaussian distributions,

$$p'(X_k) = \frac{1}{\mathrm{fN}} \sum_{n=1}^{\mathrm{fN}} \frac{1}{2\pi h^2} \exp\left\{ -\frac{||X_k - X_n||^2}{2h^2} \right\}, \quad (1)$$

where X_k is a coordinate of an arbitrary pixel (k) in a painting, X_n is a coordinate of a fixation point and fN is the total number of fixation points. h is a standard deviation which we set at 22.5. Since (1) has an infinite support, we restricted the support to the size of the painting by normalizing as

$$p(X_k) = \frac{1}{\sum_{k=1}^{\mathrm{N}} p'(X_k)} p'(X_k), \qquad (2)$$

where N is the number of pixels of the painting and p is the density function of fixation points from a painting observation. We shall call p a fixation distribution, which is compared to the saliency map of the same painting.

B. Similarity to the saliency map

To quantify the similarity between a saliency map and human fixations, we use a statistical relationship between the two distributions with the same method as [10]. Before the measurement, the saliency map also needs to be remodeled as a probability density function. The salience value Sv of each pixel was calculated (Fig. 2) using the matlab toolbox [11, 12] for saliency maps by Itti and Koch [3] and normalized by the painting size. Then the correlation coefficient (CC) between the normalized Sv and the fixation distribution (p) was calculated as the similarity between the saliency map and the fixation distribution. This similarity is the salience effect Se and can be computed as

$$Se = \frac{\sum_{k=1}^{\mathrm{N}} Sv(X_k) p(X_k)}{\sum_{k=1}^{\mathrm{N}} Sv(X_k)}. \qquad (3)$$

Se values were then compared between artists and novices and between the two sessions for each subject type.

C. Similarity between fixation distributions

We need to confirm whether fixation distributions are similar or not in each subject type (artists or novices) to examine whether they attended to the same features or not. The similarities were also measured with the CC between a pair of fixation distributions. We call the CC similarity of fixation locations Sfl. The Sfl values were compared between three combination types: all pairs of the artists, all those of the novices and those between the artists and the novices with Tukey's multiple comparison test for each session. The Sfl values of each combination type were also compared between two sessions.

IV. Results

A. Similarity to saliency map

In the free viewing session, the average Se of artists was significantly lower than those of novices (t test, p = 0.04). In contrast, in the preference judgment session, we found no significant difference between the Se of the artists and those of the novices (Fig. 2). In a comparison between the two different sessions, the average Se of the artists in the free viewing session was lower than those in the preference judgment session but no significant difference was found. Similar to the Se of the artists, the Se of the novices in the free viewing session also had no significant difference from those in the preference judgment.

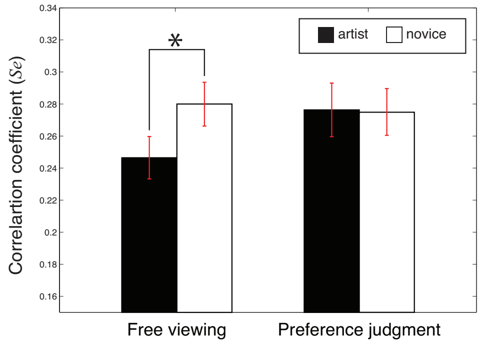

Fig. 2. The means and SEs of Saliency effects (Ses).
*: $p < 0.05$ among artists and novices.

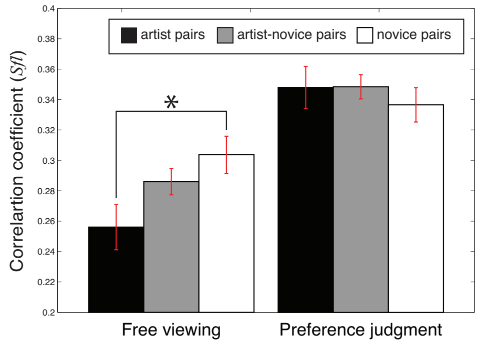

Fig. 3. The means and SEs of Correlation coefficients between paired fixation distributions.
*: $p < 0.05$ among all pairs of artists and those of novices.

B. Similarity between fixation distributions

Fig. 3 shows the Sfl for each painting. In the free viewing session, the average Sfl of all pairs of artists was significantly lower than those of novices (Tukey's method, p = 0.0478) but not in the other comparisons. In the preference judgment session, no significant difference was found in any comparison of the three combination types. In a comparison between two sessions, the average Sfl of each combination type in the free viewing session was significantly lower than those in the preference judgment session respectively (artist pairs: t test, p = 9.4928e-06; novice pairs: t test, p = 0.0195; artist-novice pairs: Welch"s test, p = 8.8296e-08.).

V. Discussion

In this study, we have showed that the relation between the saliency effect Se of the artists and the novices varied with the task type. In the free viewing session, the novices attended more to early visual features such as high contrast of hue than artists. In the preference judgment session, however, no difference was found between the artists and the novices.

A previous study showed that fixation pattern varied in different tasks [5]. There, the subject observed a painting in which few persons and the other objects such as furniture in the room were represented. Before the experiment, the subject was instructed to guess the ages of the people in the painting and to remember the object positions. Then, the subject fixated on the different locations between the two tasks. The preference judgment session in our study, however, is not likely to give the subject any clear strategies. On the other hand, the saliency map [3, 4] often corresponds to human visual attention in free viewing [6]. Accordingly, no difference between two sessions may suggest that the novices have no clear knowledge to observe abstract paintings in a vague task.

In the free viewing session, the artists attended less to the salient features than the novices. The salient locations may have a role as a region of interest (ROI) of a meaningful target [2]. There the novices attended less to the ROI set as a face or a human figure than the artists in free viewing. This difference may be because the artists have specific knowledge for their individual task in observing the abstract paintings. No significant difference of Se, however, was found between the artists and novices in the preference judgment session. The artist's specific knowledge appeared to be assorted from those of the novices merely in free viewing of abstract paintings.

Concerning the similarity of fixation locations Sfl, in the free viewing session, the Sfl of all pairs of the artists was lower than that of the novices although the other comparisons were not significantly different. This indicates that the fixated locations were not similar in each subject type although each artist attended to different features while the novices attended more to salient features than the artists. Each artist possibly have different prior knowledge to observe abstract paintings. The difference may be caused by a difference of their art styles such as Japanese painting and Comic art because human attention relates to learning [13]. In contrast, in the preference judgment, the Sfl values of three combination types were not significantly different from each other. In addition, the Sfl of each combination type was higher in this session than in the free viewing session. This indicates that both the artists and the novices attended more to the same locations from each other in the preference judgment session than in the free viewing session. Taking no difference of Ses between the two sessions into consideration, in the preference session, another type of visual feature may have attracted their attention. For a preference judgment task, the more effective features extracted by other attention models may estimate their fixation locations [14]. Another cause of the difference in the two sessions may be due to the evaluation method. In this study, even though the different painting set was used in each session, the Se was compared for each session without considering the distribution of saliency maps of 20 paintings. Therefore the difference of the painting set was merely shown in the difference of the fixation distributions between two sessions.

In summary, the artists attended less to salient features than the novices in the free viewing session but not in the preference judgment session. In this study, Itti and Koch's saliency map was used as a base of fixation points although other models are still suggested in recent studies. In addition, we may find the difference between artists and novices with spatiotemporal analysis regarding the attention models.

VI. Conclusions

In this study, we showed that artists attended less to early visual features such as high contrast of hue than novices in the free viewing session. Although this difference was not found in the preference judgment session. In the free viewing session, the artists fixated on different locations from each other while the novices fixated on early visual features. In contrast, in the preference judgment session, both the artists and novices fixated on similar locations.

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