Vision Research 130 (2017) 76–84

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

The colors of paintings and viewers' preferences

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ARTICLE INFO

Article history:
Received 14 June 2016
Received in revised form 1 November 2016
Accepted 28 November 2016

Keywords:
Colors of paintings
Color vision
Aesthetic preference
Visual arts
Art statistics

ABSTRACT

One hypothesis to explain the aesthetics of paintings is that it depends on the extent to which they mimic natural image statistics. In fact, paintings and natural scenes share several statistical image regularities but the colors of paintings seem generally more biased towards red than natural scenes. Is the particular option for colors in each painting, even if less naturalistic, critical for perceived beauty? Here we show that it is. In the experiments, 50 naïve observers, unfamiliar with the 10 paintings tested, could rotate the color gamut of the paintings and select the one producing the best subjective impression. The distributions of angles obtained are described by normal distributions with maxima deviating, on average, only 7 degrees from the original gamut orientation and full width at half maximum just above the threshold to perceive a chromatic change in the paintings. Crucially, for data pooled across observers and abstract paintings the maximum of the distribution was at zero degrees, i.e., the same as the original. This demonstrates that artists know what chromatic compositions match viewers' preferences and that the option for less naturalistic colors does not constrain the aesthetic value of paintings.

1. Introduction

The processes of aesthetic experience have been studied scientifically since Gustave Fechner (Fechner, 1876), from psychology (Palmer, Schloss, & Sammartino, 2013) to neuroaesthetics (Cinzia & Vittorio, 2009; Jacobsen, 2010; Zeki, 1999), but the underlying mechanisms and laws are still largely unknown. Yet, successful artists seem to have implicit knowledge of how to make beautiful works of art. Aesthetic faces like that of the Egyptian Queen Nefertiti were produced thousands of years ago based on intuitive knowledge of the laws of averageness and symmetry in the aesthetic value of faces (Ascaso, Lizana, Singh, & Dua, 2011). Monet used implicit knowledge of the brain processing of brightness and color to create the illusion of sun's motion in *Impression Sunrise* (1872) (Conway & Livingstone, 2007; Livingstone, 2002).

How much specific features of a painting contribute to its general beauty is, however, difficult to quantify. Neuroaesthetic studies have revealed that when paintings are presented to observers they induce different patterns of activity in the brain depending whether they are considered beautiful or otherwise unappealing (Ishizu & Zeki, 2011; Kawabata & Zeki, 2004). The properties of the paintings underlying this brain activity are, however, unclear (Conway & Rehding, 2013). One reasonable hypothesis that has been considered is that the aesthetic value of paintings depends on the extent to which they mimic natural image statistics (Fernandez & Wilkins, 2008; Graham & Redies, 2010). In fact, even though their representations often do not obey the laws of physics (Cavanagh, 2005; Mamassian, 2008) and their dynamic range of luminance is limited (Graham & Meng, 2011), paintings share some important spatial statistical regularities with natural scenes, e.g., scale-invariance (Graham & Field, 2008; Graham & Redies, 2010; Simoncelli & Olshausen, 2001; Taylor, Micolich, & Jonas, 1999). These properties may have aesthetic value (Spehar, Clifford, Newell, & Taylor, 2003) and deviations from natural image statistics may even lead to unpleasant visual experiences (Fernandez & Wilkins, 2008; Juricevic, Land, Wilkins, & Webster, 2010). Similarly, in the color domain, paintings, even of abstract nature, have several chromatic statistical regularities common to natural scenes (Montagner, Linhares, Vilarigues, & Nascimento, 2016; Tregillus & Webster, 2016).

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http://dx.doi.org/10.1016/j.visres.2016.11.006
0042-6989/

Yet, at least in one aspect, paintings and natural scenes seem to differ. In an analysis based on hyperspectral imaging data from 50 natural scenes and 44 paintings the orientation of the color gamut of individual paintings in two-dimensional color space was, on average, tilted to red, i.e., painters tend to use more saturated reddish colors (Montagner et al., 2016). This somewhat non-naturalistic chromatic compositions can be a consequence of constrains imposed by pigments. Even though the gamut provided by pigments is relatively uniform across the color space (Johnston-Feller, 2001) this hypothesis cannot be ruled out. Or, it can be an option guided purely by aesthetical factors. Preference data based on a very limited pool of observers and paintings suggest the possibility that the best chromatic composition is very close to the original one (Nascimento et al., 2015). Existing theories of color preference do not provide useful insights to the problem as they apply only to single colors (Palmer & Schloss, 2010) or pairs of colors (Schloss & Palmer, 2011). Theories of color harmony (Moon & Spencer, 1944) consider more complex compositions but are difficult to apply to complex paintings (O'Connor, 2010).

Is the chromatic composition of a painting, even if less naturalistic, critical for its aesthetic value? Here, we investigated this question with an experiment where a large number of naïve observers, unfamiliar with the paintings tested and without formal artistic education, rotate the color gamut of paintings, abstract and realistic, to obtain their preferred composition. The colors of the original paintings were derived by precise hyperspectral imaging and the chromatic manipulations were visualized with a calibrated monitor. All paintings but one had color gamut orientations untypical of natural scenes. Thresholds for perceiving chromatic changes in each painting were also measured and compared with the variability of preferred compositions. The data obtained with naïve observers were compare with data for analogous experiments carried out by art experts and, in particular, experts in some of the paintings tested.

2. Methods

2.1. Paintings

Ten paintings were selected for the experiments. Images of the paintings are represented in Fig. 1A. Six paintings (A–F) are of abstract nature and four (G–J) have realistic elements. Paintings A, B, C, D, G and H are oil paintings on canvas from Amadeo de Souza-Cardoso (1887–1918), an important Portuguese painter (Freitas & Alfaro, 2008), and belong to the collection of Centro de Arte Moderna da Fundação Calouste Gulbenkian, Lisboa, Portugal. E and F are oil paintings from unknown painters. J is signed by Wan Kteben and is from the Renaissance époque painted on wood. I was painted by Carlos Ramos on wood and is from XIX century. Both belong to the collection of the Museu Nogueira da Silva, Braga, Portugal. No varnish aging or pigments degradation were perceptible in any of the paintings. Paintings were selected such that their colors when simulated illuminated by the standard illuminant D65 fitted, at least, 90% inside the volume of the colors that could be reproduced by the monitor display used in the experiments.

2.2. Observers

Three groups of observers (G1, G2, and G3) carried out the experiments. G1, the naïve group, had 50 observers with no previous knowledge of the paintings neither any formal artistic education (12 males, 38 females, mean age = 25 y, SD 9). They were recruited mainly form the students and academic staff from the University of Minho. To test their previous knowledge about the paintings a written inquiry was carried out after they finished the experiments. They were shown the original images of the paintings and asked whether they were familiar with them before the experimental sessions. If more than one painting was signaled as familiar the observer was excluded from the study. If only one painting was familiar, the data corresponding to that painting was excluded from the analysis (five out of the fifty observers were in this condition). These observers carried out the experiments in the color laboratory of the University of Minho. G2, the art experts group, had 8 experts in art who were aware of the painter Amadeo de Souza-Cardoso but were unfamiliar with the paintings tested (three males, five females, mean age = 47 y, SD 7). They were art teachers, specialists in conservation and restoration. G3, the Amadeo experts group, had 6 experts in the paintings of Amadeo de Souza-Cardoso (one male, five females, mean age = 35 y, SD 4). They were art historians, curators and PhD students in history of art and painting conservation. One of these observers, CA, is co-author of this paper. G2 and G3 were selected to investigate how the knowledge of artistic production and style, the ability to interpret art and the training in observation of art, may influence the results. All observers had normal or corrected-to-normal acuity and normal color vision. Observers of group G1 had their color vision tested with Rayleigh anomaloscope (Oculus Heidelberg Multi-Color), Cambridge Color Test (Regan, Reffin, & Mollon, 1994), Ishihara plates and the Color Assessment and Diagnosis Test (Jennings & Barbur, 2010). Observers of group G2 and G3 had their color vision tested with Ishihara plates and Farnsworth-Munsell 100 Hue Color Vision Test. The experiments were performed in accordance with the tenets of the Declaration of Helsinki and informed consent was obtained from all observers.

2.3. Stimuli and experimental set-up

The stimuli for the experiments were images of the paintings synthetized from hyperspectral imaging data. The paintings were digitalized with a hyperspectral imaging system at the Centro de Arte Moderna da Fundação Calouste Gulbenkian, Lisboa, Portugal (A–D and G, H), at the Museu Nogueira da Silva, Braga, Portugal (I, J) and at the color laboratory of the University of Minho (E, F). Detailed description of the system and acquisition methodology is given elsewhere (Pinto, Linhares, & Nascimento, 2008). The spectral accuracy of the hyperspectral system in recovering spectral reflectance factors of colored samples is within 2% (Foster, Amano, Nascimento, & Foster, 2006; Nascimento, Ferreira, & Foster, 2002). The paintings were simulated illuminated by the standard illuminant D65 and the corresponding coordinates of each pixel in the CIELAB color space computed. Together, these points in this three-dimensional space represent the color volume of each painting, i.e., its three-dimensional color gamut. In the experiments, observers could change the chromatic composition of the paintings using a joy-pad. The effect of actuating on the joy-pad was to simulate on the display screen a rotation of the color volume around an axis parallel to the L^* axis through the average CIELAB (a^*, b^*) of each painting. The original composition corresponded always to zero degrees. Fig. 2 represents the color volume of one of the paintings and illustrates the aforementioned gamut manipulation.

Fig. 1B shows the color gamut of each painting in the CIELAB (a^*, b^*) plane. The ellipses shown were fitted to the data based on a least-squares criterion, covering on average 88% of the data points. The angular orientation of the color gamut of each painting is characterized by the angle of the major axis of the best-fitted ellipse in relation to the positive CIELAB a^* axis. These angles are indicated on the right of the corresponding graphs in Fig. 1B. All paintings but one (painting I, Fig. 1A) have gamut orientation lower than