Estimating the Colors of Paintings

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Abstract. Observers can adjust the spectrum of illumination on paintings for optimal viewing experience. But can they adjust the colors of paintings for the best visual impression? In an experiment carried out on a calibrated color monitor images of four abstract paintings obtained from hyperspectral data were shown to observers that were unfamiliar with the paintings. The color volume of the images could be manipulated by rotating the volume around the axis through the average *(a*, b*)* point for each painting in CIELAB color space. The task of the observers was to adjust the angle of rotation to produce the best subjective impression from the paintings. It was found that the distribution of angles selected for data pooled across paintings and observers could be described by a Gaussian function centered at 10°, i.e. very close to the original colors of the paintings. This result suggest that painters are able to predict well what compositions of colors observers prefer.

Keywords: Colors of paintings · Color vision · Art visualization · Color rendering · Aesthetics

1 Introduction

The visual impression from paintings and other artworks is dramatically influenced by the energy and color of the illumination. It has been shown empirically that an ideal illumination spectrum can be spectrally tuned for each painting [1-4]. Although a light source with a correlated color temperature close to that of skylight appears to be suited for most of the paintings [3] it is still unclear what determines observers' preferences. These results are relevant for museums to optimize their art displays but also for virtual displaying of artworks.

What chromatic composition would be obtained if instead of spectrally tuning the illumination observers tune the colors of the paintings by some global transformation? How close that composition would be to the original one produced by the artist?

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The aim of this work was to investigate which composition of colors selected from a large set of possibilities observers prefer for each artwork. Abstract paintings were digitalized by hyperspectral imaging and their spectral reflectance estimated for each pixel. The transformation of colors selected was a rotation of the color volume. Thus, the original colors of the paintings could be changed by rotating the corresponding color volume around the axis defined by the average color in CIELAB color space. In an experiment on a calibrated color monitor observers that were unfamiliar with the paintings adjusted the rotation angle to obtain the preferred composition. Results indicate that they select a composition very close to the original one.

2 Methods

2.1 Paintings

Four paintings from Amadeo de Souza-Cardoso (1887-1918) were selected for testing. Images of the paintings are shown in Figure 1. The paintings belong to the collection of Centro de Arte Moderna da Fundação Calouste Gulbenkian, Lisboa, Portugal. These paintings were selected because they are of abstract nature and chromatically rich (see Figure 1).

2.2 Stimulus

The paintings were digitalized at the museum with a hyperspectral imaging system. Detailed description of the system and methodology is given elsewhere [2]. Only the essential information is repeated here. The digitalization was from 400 to 720 nm at 10 nm intervals using a fast-tunable liquid-crystal filter (Varispec, model VS-VIS2-10-HC-35-SQ, Cambridge Research & Instrumentation, Inc.,Massachusetts) and a low-noise digital camera (Hamamatsu, mod. C4742-95-12ER, Hamamatsu Photonics K. K., Japan), with a spatial resolution of 1344 × 1024 pixels and 12 bit intensity. The spectral reflectance of each pixel of the paintings was estimated from a gray reference surface present close to the painting at the time of image acquisition. Illuminant spatial non-uniformities and angular variations in the system transmittance were compensated using measurements of a uniform surface imaged in the same location and under the same illuminating conditions as the paintings.

Stimuli were images of the paintings transformed by a variable chromatic rotation around an axis in the in CIELAB color space. First, the painting was simulated illuminated by D_{65} and the corresponding coordinates of each pixel in CIELAB space were computed. Figure 2 shows for illustrative purposes the tridimensional representation of the top right painting shown in Figure 1. The chromatic center of this volume was then computed and an axis parallel to the L* dimension through this point adopted as the axis of the chromatic rotation. In the experiment the observer could adjust the angle of rotation by actuating on a joy-pad. The rotational step could be selected by the observers to be 1^{o} or 6^{o}.

The paintings were presented on the computer screen with an average luminance of 20 cd/m^2. The viewing distance was 1 m and the paintings subtended on the screen a visual angle of about 10^o ×10^o.

Fig. 1. Images of the four paintings tested. They are from Amadeo de Souza-Cardoso (1887-1918) and belong to the collection of Centro de Arte Moderna da Fundação Calouste Gulbenkian, Lisboa, Portugal. The stimuli for the experiments were images of the paintings derived from hyperspectral imaging data collected at the museum.

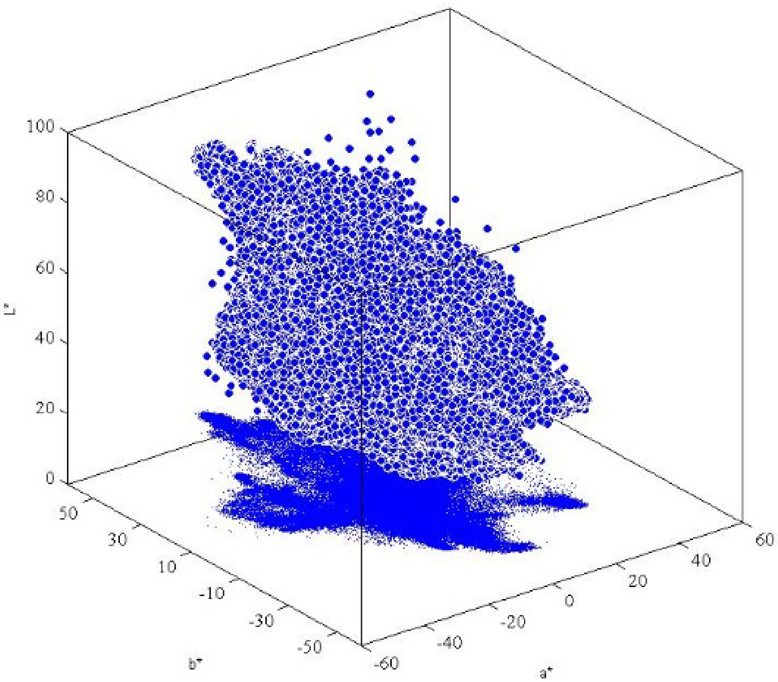

Fig. 2. Representation of the CIELAB color volume of the top right painting shown in Figure 1. In the experiment the observers could vary the angle of rotation of the color volume around the axis through the average (*a**, *b**) in CIELAB space and view the corresponding image on the screen.

2.3 Apparatus

The images were displayed on a CRT monitor (GDM-F520, Sony Corp., Japan) controlled by a video board (ViSaGe Visual Stimulus Generator; Cambridge Research Systems, Rochester, Kent, UK) in 24-bits-per-pixel true-color mode. The monitor was calibrated in color and luminance with a telespectroradiometer (PR-650 SpectraScan Colorimeter; Photo Research, Chatsworth, CA). The stimuli were displayed with half of the original spatial resolution and a frequency of 80 Hz.

2.4 Procedure

In the beginning of each trial a painting selected at random from the set of four was presented with its colors rotated in CIELAB color space by angle selected at random in the range $+180^o$ - -180^o. The task of the observer was to adjust the angle of the chromatic rotation such that the painting produced the best subjective impression. For the adjustment the observers used a joy-pad. No indication was given to the observers about the effect of the adjustment, they just perceive a change of the colors of the paintings. There was no time limit for each trial. Experiments were carried out in a darkened room. In each session each painting was tested 3 times in a random order. Each observer performed a total of 3 sessions.

2.5 Observers

There were 7 normal observers all unware of the purpose of the experiment and without previous knowledge of the paintings to be tested. They also did not have any formal artistic education. Each had normal or corrected-to-normal acuity. Their color vision was teste with Rayleigh anomaloscope (Oculus Heidelberg Multi Color), Cambridge Colour Test[5], Ishihara plates and the Color Assessment and Diagnosis Test[6]. The experiments were performed in accordance with the tenets of the Declaration of Helsinki, and informed consent was obtained from all observers.

3 Results

Figure 3 shows the histogram of the responses for two of the paintings tested with data pooled across observers. The histogram on the left corresponds to the painting represented on the bottom right of Figure 1 and the histogram on the right to the painting represented on the top left of the same figure. Figure 4 shows the histogram of the responses of observers with data pooled across observers and paintings. The horizontal axis represents the angular rotation of the adjustments in degree. The vertical axis represents the number of times each angle was selected as producing the best subjective impression. Bin size is 20°. In Figure 4 the solid line represents a Gaussian fit to the data with a maximum at 10° and FWHW of 80°.

The data shows that observers have a clear common preference which is very close (within about 10°) to the original composition. As they were unfamiliar with the paintings and did not have any formal artistic education, the selection of colors may be determined by some fundamental property of the visual system.

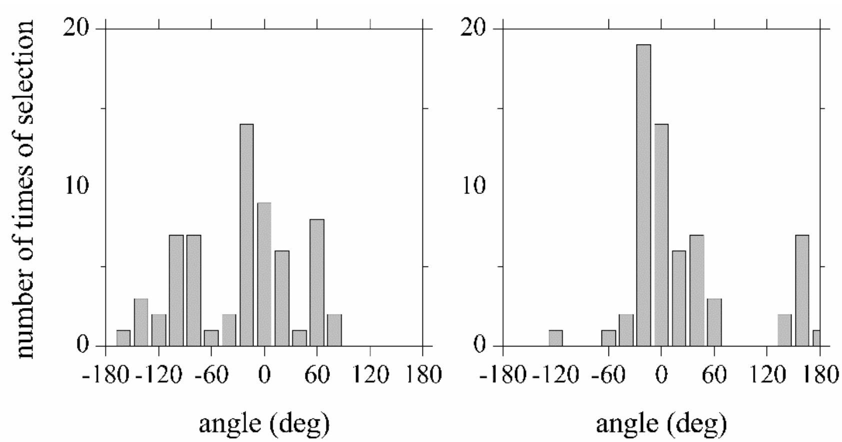

Fig. 3. Histogram of observers' responses based on data pooled across observers for two of the paintings tested. The histogram on the left corresponds to the painting represented on the bottom right of Figure 1 and the histogram on the right to the painting represented on the top left of Figure 1. The horizontal axis represents angular rotation and the vertical axis represents the number of times each angle was selected as producing the best visual impression. Bin size is 20°.

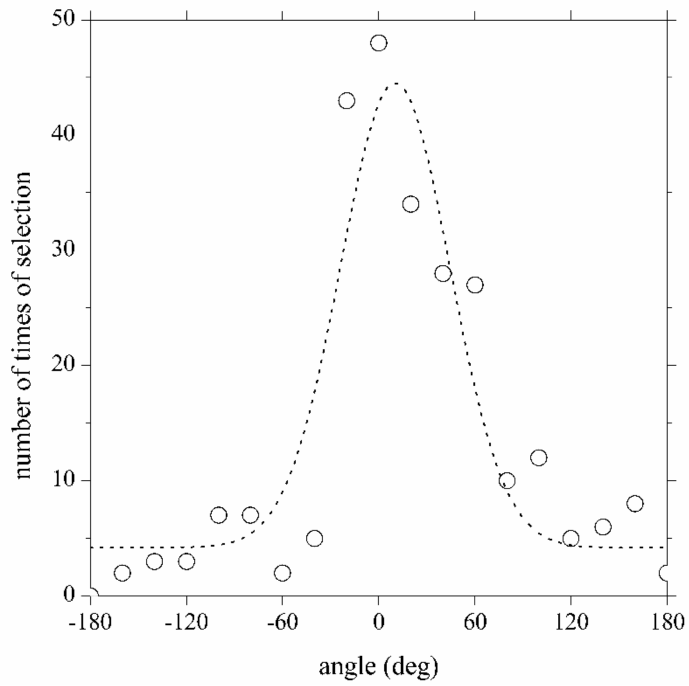

Fig. 4. Histogram of observers' responses based on data pooled across observers and paintings. The horizontal axis represents angular rotation and the vertical axis represents the number of times each angle was selected as producing the best visual impression. Bin size is 20º. The solid line represents a Gaussian fit to the data with a maximum at 10º and FWHW of 80º.

4 Discussion and Conclusions

In the psychophysical experiment described here observers adjusted the chromatic composition of unfamiliar abstract paintings to obtain the best subjective visual impression. The results show that they clearly prefer a chromatic composition very close to the original.

The chromatic transformation selected to manipulate the colors of the paintings was a rotation of the color volume around the axis through the average color of the paintings. Although other kinds of global chromatic transformations could have been selected this choice is convenient as it is simple to implement, provides a continuous change of each color, avoids gamut problems like those posed by volume expansion-compression and does not produce spatial artifacts like those posed by permuting the colors of the palette.

What information are observers using to select a specific chromatic composition for each painting that is unfamiliar? They could be using memory color based on realistic elements of the paintings. The representations of real elements, e.g. windows, guitar, face, among others, is so distorted in these painting that it is unlikely they can be seen as chromatic references.

Several studies have been exploring quantitatively the relationships between artworks and the visual system [7] and, in particular, to what extent they reproduce properties of natural scenes [8]. The properties of the paintings tested here do not have evident similarities with natural scenes thus it is unlikely they underlie observers' choices. In any case, the findings reported here suggest that some fundamental property of vision is intuitively known by painters.

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