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The colors of paintings and viewers' preferences

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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 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.

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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

* Corresponding author. *E-mail address:* smcn@fisica.uminho.pt (S.M.C. Nascimento). 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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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 nonnaturalistic 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. I 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 v, SD 4). They were art historians, curators and PhD students in history of art and painting conservation. One of these observers, CA, is coauthor 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



Fig. 1. Preferred chromatic composition and thresholds to perceive a chromatic change for naïve observers. (A) Images of the paintings. Six paintings, A–F, are abstract compositions 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) and belong to the collection of Centro de Arte Moderna da Fundação Calouste Gulbenkian, Lisboa, Portugal. 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. E and F are oil paintings from unknown painters. The stimuli for the experiments were images of the paintings derived from hyperspectral imaging data and displayed on a calibrated CRT monitor. (B) Angular orientation of the color gamut of each painting characterized by the angle of the major axis of the best fitted ellipse in relation to the positive CIELAB *a** axis. (C) Preferred gamut orientation – pooled data. In this graphs the orientations are expressed relatively to the original gamut orientation, thus zero degrees corresponds to the original painting. Histogram of the responses from 50 observers for each painting and the corresponding best-fitting normal distribution; the numbers represent the angular position of the corresponding positive and negative best-fitting normal distributions; the numeric values represent the thresholds obtained using a non-parametric approach for a criterion of 50% (see Section 2 for details).



Fig. 2. Manipulation of the color volume. (A) Colour volume in CIELAB color space of painting D computed assuming the standard illuminant D65. (B) Images of painting D synthesized by rotating the corresponding color volume by a variable angle indicated above each image. Graphs at the bottom represent the projection of the gamut in the CIELAB (a^* , b^*) plan of the corresponding images. For simplicity only part of the points are represented. In the experiments, the observers could change the angle of the color volume of the paintings by using a joy-pad. The task of the observers was to adjust the angle such that the painting produced the best subjective impression. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

92°, the average gamut orientation for natural scenes (Montagner et al., 2016).

The images of the paintings were presented on the monitor display with an average luminance of 12 cd/m². The viewing distance was 1 m and the images subtended on the screen a visual angle from $5.9^{\circ} \times 5.1^{\circ}$ to $13.7^{\circ} \times 10.3^{\circ}$, depending on the original size of the paintings. Images were subsampled every other pixel from the original resolution of 1344×1024 pixels, then cropped from one of the edges to avoid the reflectance standard. The monitor was a 24'' CRT (GDM-F900 Triniton Color Graphic Display, 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 a frequency of 100 Hz and a screen resolution of 1264 \times 790 pixels.

The images of the original paintings fitted, on average, 97% inside the volume of colors that could be reproduced by the monitor

display. The worst case fitted 91% and the best 100%. For the original images of the paintings, the average chromatic error for the pixels out of gamut expressed in CIELAB color space was $\Delta E_{ab}^* = 2.4$, i.e., near threshold for complex images (Aldaba et al., 2006; CIE, 2011; Liu, Huang, Cui, Luo, & Melgosa, 2013). For rotations of the color gamut, gamut compression occurred as each color out of gamut was projected to the closest one displayable. This produced some variation in the average saturation, but this variation was always below 3.8 in ΔE_{ab}^* , i.e., close to threshold for complex images.

2.4. Design and procedure

In the first experiment the goal was to determine the preferred chromatic composition for each painting and observer. Each painting was tested 3 times, in randomized order, in a single experimental session. In the beginning of each trial the painting selected was presented on the monitor with its colors corresponding to a randomized rotation of its original color volume. The task of the observer was to actuate on the joy-pad to change the chromatic composition to obtain the best subjective impression. The task for the Amadeo experts (G3) when testing Amadeo's paintings was to adjust the chromatic composition to obtain the image that better matched their memory of the paintings. For the adjustment the observers could select steps of six or two degrees. No indication was given to the observers about the effect of the adjustment, they just perceived a change of the colors of the paintings. There was no time limit for each trial.

In the second experiment the goal was to estimate for each painting and observer the threshold to perceive a chromatic change from the original colors. This threshold was expressed as an angle of rotation of the color volume in relation to the original chromatic composition. In the beginning of each trial the painting selected was presented with its original composition simulated under standard illuminant D65. The task of the observer was to press a button on the joy-pad until they see any change in the painting. When observers were pressing the control the angle of the color volume rotated in steps of one degree in the positive or negative angular direction. In each experimental session in the laboratory of the University of Minho (G1) each painting was tested 6 times in a random order, three in the positive angular direction and three in the negative angular direction. In the experimental sessions outside the laboratory (G2 and G3) each painting was tested 4 times, twice in each angular direction. Thresholds for positive and negative angular changes were computed using a criterion of 50% from a non-parametric approach that makes no assumption about the shape of the true function underlying the experimental data, except its smoothness (Zchaluk & Foster, 2009).

The experiments with G1 were carried out at the color laboratory of Minho University, experiments with G2 were carried out at the Árvore – Cooperativa de Actividades Artísticas, Porto, and the experiments with G3 were carried out at the Fundação Calouste Gulbenkian, Lisbon. In all conditions experiments were carried out using the same equipment and in darkened rooms with no windows.

3. Results

3.1. Preferred gamut orientation

Fig. 1C shows the histograms of the preferred gamut orientation for data pooled across 50 naïve observers and the corresponding

best-fitting normal distributions. In this graphs the orientations are expressed relatively to the original gamut orientation, thus zero degrees corresponds to the original painting. The numbers on top of each graph represent the maximum angle of each distribution. The averages of the corresponding absolute values are 3.3° and 12.0° for abstract and realistic paintings, respectively. Fig. 3A compares the maxima of the best-fitted normal distributions obtained for naïve observers with those obtained by Amadeo experts. The task for the experts when testing Amadeo's paintings was to adjust the composition to match their color memory of the paintings. The averages for experts are 4.8° and 9.5° for abstract and realistic paintings, respectively. If only Amadeo's paintings are considered, the averages for abstract paintings are 4.8° and 5.8° for naïve and experts, respectively; for realistic paintings they are 14.0° and 8.0° for naïve and experts, respectively. For both groups the larger angles are obtained for paintings where the representation of skin can be seen, i.e., paintings G. H and I. Data for art experts (G2) were similar to data for naïve and are presented in Fig. 6. In these analyses the histogram bins for G1 were 10° and for the other groups, which had fewer observers, were 20°.

The variability of responses in this experiment can be quantified by the full width at half maximum (FWHM) of the best-fitting normal distributions. The lines in Fig. 3A show these data for naïve and Amadeo experts. For convenience of representation, half of the FWHM is represented in the positive axis and half in the negative. The global response pattern across paintings is similar for the two groups of observers. Experts, however, showed much less variability. For naïve observers, intra-observer variation was 42°, interobserver variation was 10° and variation across paintings was 16°. For Amadeo experts, intra-observer variation was 16°, interobserver variation was 2° and variation across paintings was 17°. Amadeo experts knew Amadeo's paintings and were trying to reproduce their memory images rather than selecting the preferred chromatic composition. Their data represent, therefore, an estimate of a lower limit for observers' variability in the preference task. Again, data for art experts (G2) were similar to data for naïve and are presented in Fig. 6.

Fig. 4A shows the preferred gamut angle for naïve observers expressed as a function of the original gamut angle for each painting. In the graphs of this figure the preferred gamut angle is expressed in relation to the positive CIELAB *a*^{*} axis and is obtained by combining the values indicated in Fig. 1B (original gamut angle)



Fig. 3. Comparison of naïve observers with Amadeo experts. (A) Each symbol shows for each painting the maximum of the best-fitting normal distribution to the cumulative preference data for naïve (solid circles) and experts (open circles). Error bars show the standard error where sufficiently large. The lines represent the FWHM of the best-fitting normal distributions for the naïve (dotted) and experts (solid). For convenience, half of the FWHM is represented in the positive axis and half in the negative. (B) Each line shows the thresholds to perceive a chromatic change for the naïve (dotted) and Amadeo experts (solid).



Fig. 4. Preference, variability and relative rate of aesthetic preference for naïve observers. (A) Preferred gamut angle expressed as a function of the original gamut angle. The straight line represents the line of unitary slope. (B) Variability of the data represented as FWHM of the fitted normal distributions expressed as a function of the original gamut angle. (C) Relative rate of aesthetic preference for each painting at 92°, the average angle for natural scenes, obtained by computing the relative height of the fitted normal distributions at that angle. The straight line through the data represents the best linear fit.

with those of Fig. 1C (preferred gamut angle). This graph shows that observers' selections are painting specific. On the other hand, the data does not suggest a systematic tendency towards selecting more naturalistic angles but rather a random distribution around the line of unitary slope. Fig. 4B shows the variability of the data expressed as FWHM of the fitted normal distributions as a function of the original gamut angle. Also, no clear systematic pattern can be observed in the data.

The angle of 92° , the average angle for natural scenes (Montagner et al., 2016), is in the threshold region for two paintings and close to it for the other eight. An estimate of the relative rate of aesthetic preference for each painting at 92° can be obtained by computing the relative height of the fitted normal distributions at that angle. These data are shown in Fig. 4C as function of the original gamut angle. As the original gamut angle decreases the relative rate of aesthetic preference at 92° also decreases, suggesting that the appreciation is not related with how much the gamut angle approaches the average angle for natural scenes.

Fig. 5 shows the histograms for preference data pooled across abstract and realistic paintings for naïve observers and Amadeo experts. The dotted lines through the data represent the bestfitting normal distributions and the numbers above represent the maximum of each distribution. The numbers in the middle of the distributions represent FWHM. The graphs for the experts include only data from Amadeo's paintings. For abstract paintings, naïve observers selected more often an angle of zero degrees, i.e., the exact original composition. The corresponding angle for experts was 6°. For the realistic paintings, naïve observers select an angle of 7° and the experts an angle of 2°. Consistently with what was described above, FWHM for experts are considerably lower than for naïve.

3.2. Thresholds to perceive a chromatic change

Fig. 1D shows the histograms of the responses in the threshold experiment for data pooled across 50 naïve observers and the corresponding best-fitting normal distributions. Data is shown for changes in the positive and negative angular directions. The numbers on the right and left represent the thresholds obtained as described in the Section 2. Fig. 3B compares these thresholds with those obtained by Amadeo experts. These measurements are independent of the prior knowledge of the paintings, thus very similar data were obtained for the two groups. Significantly, thresholds for the naïve observers were, on average, only a little smaller that the FWHM obtained on the preference experiment (Fig. 3A). Data for art experts (G2) were similar to data for naïve observers and are presented in Fig. 6.

4. Discussion

Here we describe a set of experiments in which observers adjusted the angle of the color gamut of unfamiliar paintings to obtain the best subjective visual impression. The results show that they prefer a chromatic composition very close to the original. All but one of these paintings had a color gamut with angular orientation different from typical natural scenes. The data suggest, therefore, that the aesthetical value of the paintings is not determined or constrained by the naturalistic aspect of the color gamut, i.e., by the extent by which the angle of the color gamut resembles those of natural scenes. Rather, other visual cues underlie perceived beauty and these are known intuitively by the painters.

The rotation of the color gamut preserves lightness, saturation and the relationships between colors in the image. Strictly, there is a slight change in saturation because the rotation is not around the origin of the color space but around the point representing the average color of each painting. Also, the rotation causes a variable gamut compression due to the limited volume of the colors reproducible by the monitor. These changes were, however, very small. The saturation variations were bellow or at the level of the thresholds for detecting a chromatic change and therefore irrelevant for the experiment. On the other hand, one could speculate that saturation cues could still be present because of the limitations of the CIELAB in representing perceived saturation. There is good evidence, however, that CIELAB is indeed a good space to represent saturation (Schiller & Gegenfurtner, 2016).

Memory of colors of familiar objects represented in the paintings, e.g., skin or vegetation, could be used as cues to the original composition of the paintings. Because six of the paintings are abstract compositions it is unlikely that memory color has any influence in the experiment. Moreover, the average preferred angle for abstract paintings was closer to the original than for paintings with realistic elements $(3.3^{\circ} \text{ versus } 12.0^{\circ})$. On the other hand, it may happen that an observer remembers a palette characteristic of a specific painter and use this information as a cue to identify the original composition of paintings belonging to the same artist. In our case, the tested paintings were unknown to naïve observers who did not have any previous formal artistic education. Only Amadeo's paintings are known but by a restrict public. The recent



Fig. 5. Histograms pooled across paintings and observers. Histogram of observers' responses based on data pooled across observers for naïve observers (A) and for Amadeo experts (B). The graphs for the experts include only data from Amadeo's paintings. The dotted lines through the data represents best-fitting normal distributions and the numbers above represent the respective maximum. The numbers in the middle of the distributions represent FWHM. The solid line segment on the bottom represents the average threshold.



Fig. 6. Data for the group of observes G2, the art experts. (A) Each symbol shows for each painting the maximum of the best-fitting normal distribution to the cumulative preference data. Error bars show standard error where sufficiently large. The solid lines represent the FWHM of the best-fitting normal distributions. For convenience, half of the FWHM is represented in the positive axis and half in the negative. (B) Each line shows the thresholds to perceive a chromatic change in the paintings in the positive and negative angular directions.

and well-publicized exhibition of Amadeo's paintings at the Grand Palais in Paris (April–July 2016) (Freitas, 2016) occurred after the experiments were carried out.

These experiments were carried out using a specific illuminant assumed to represent average daylight with a correlated color temperature (CCT) of 6500 K. Painters are likely to have painted with natural illumination from North sky, noon light, mid-morning or mid-afternoon light, i.e., in the CCT range 5500 K–7500 K. We computed how much the color gamuts of the paintings change with illumination within this range. Angular changes are below 15°, which is bellow threshold for detecting a chromatic change (see Fig. 3B). Thus, these results are robust for this range of natural illuminations.

Although the preferred chromatic composition for all paintings was close to the original, the choices, of naïve and experts, for paintings with representation of human skin were less close. This may be because observers tried to reproduce their memory color of skin, which may not necessarily coincide with the real color (Hansen, Olkkonen, Walter, & Gegenfurtner, 2006) or with that represented in the paintings, rather than attending to the pure aesthetics of the composition. Significantly, for two of these paintings naïve and experts almost coincided in their settings (Fig. 3A). The settings for art experts (G2) were similar to those of naïve observers suggesting that the knowledge of art does not determine the preference results.

The results of this study suggest that observers' preferences are not constrained by the degree of naturalness of the angular orientation of the gamut. There are other examples in the color domain where observers' preferences are biased towards non-naturalistic conditions. For example, in studies on preferred lighting it was shown that the illuminant preferred has a spectrum more structured than daylight and produced colors more saturated than natural illumination (Masuda & Nascimento, 2013; Nascimento & Masuda, 2012). In the luminance domain, it was shown that observers prefer images with low-skewness luminance distributions over more naturalistic high skewness distributions (Graham, Schwarz, Chatterjee, & Leder, 2016). The relationships between aesthetic and naturalness are probably more complex than simple linear models can capture.

What may be the cues determining observers' choices? The only changes perceived in the experiments are hue changes. Hue relationships are, however, preserved. One hypothesis is that the rotation of the color gamut changes the hues in relation to color categories and observers prefer a chromatic composition where these categories are more balanced producing a more attractive image. Thus, in the preferred chromatic composition the relational structure of the colors is optimal. But, of course, this structure may depend on higher order properties of the images, so the same colors on a different spatial structure may not be optimal anymore. But, whatever the cues underlying observers' choices they are known intuitively by the painters who produce the almost exact composition people like.

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