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THE COLORIMETRIC BARYCENTER OF PAINTINGS

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ABSTRACT

The locations of the colorimetric barycenter or "center of gravity" of the pictorial fields of paintings were compared graphically with the geometric centers of the art works. The art stimuli consisted of reproductions of 1332 paintings of different compositional genres created by renowned Russian artists. It was observed that artists' manipulation of a color palette and their spatial control of color within a composition resulted in the location of the colorimetric barycenter of a painting corresponding closely to its geometric center for both representational and abstract paintings. This finding demonstrates the power of the center of a pictorial field to function as a balancing point about which artists exert spatial control of color among all of the compositional colors and the areas they occupy within a pictorial field.

Many artists and theoreticians interested in art experience assert that balance is the primary principle of compositional design by which the elements of a painting are organized into a cohesive perceptual and narrative whole (see, e.g., Arnheim, 1974, 1988; Bouleau, 1980; Kandinsky, 1926/1979). In paintings, a balanced composition results when the structural elements and their qualities are organized in such a way that their perceptual forces, or weights, compensate one another. Stated another way, balance is achieved when the elements of a pictorial field are pitted against each other about a balancing point or center so that the entire composition appears stable and "visually right" (i.e., "good") (Locher, 2003).

Locher, Stappers, and Overbeeke (1998) investigated the role of balance as an organizing design principle underlying adults' compositional strategies for creating visual displays. They videotaped the creation by industrial design engineering students of designs composed of different geometric shapes from the start to the completion of each black-on-white design. Locher et al. found that the barycenters of the finished designs (i.e., the "center of gravity" of a composition) were closely aligned with the geometric center of the pictorial field. In a second experiment using the same methodology, Locher, Cornelis, Wagemans, and Stappers (2001) observed that regardless of the compositional element types employed or phase of construction of a design, advanced students in an Academy of Fine Arts aligned the center of a composition with the geometric center of the pictorial field. Furthermore, the structural or physical weight of the compositional elements measured quantitatively was evenly distributed (balanced) about the principle axes of the designs throughout their construction. These findings demonstrate the power of the center of a pictorial field to function as an "anchor" or balancing point about which artists organize a composition's structural skeleton.

Artists have known for a long time that the juxtaposition of colors within a composition is a major contributing factor to its balance or harmony. Color elements in a painting may be made to contrast or assimilate to each other depending on a number of factors, such as the size, shape, and relative location of the elements within the pictorial field. Therefore, painters of representational art and many forms of abstract art select and arrange each element in a painting by its relative size, shape, and contextual meaning (in representational art) in relation to its hue, saturation and brightness (Wurmfeld, 2000). A general principle concerning the use of color found in works describing methods of composition for creating balance is that a small area of a highly saturated color can be balanced by a large area of dull, unsaturated color. This color-weight principle of color balance was quantified by Munsell (1905) in his law of inverse ratios of areas which states that the areas of colors used in combination should be inversely proportional to the product of their values (brightness) and chromas (saturation). A long history of experimental investigations that required subjects to adjust the relative areas of two Munsell color chips until the combination appeared balanced has consistently shown that Munsell's formula works quite well for predicting color balance between pairs of colors (e.g., Morris & Dunlap, 1987, 1988).

Recently, Locher, Overbeeke, and Stappers (2005) studied the interactive contribution of the color and size of the three areas occupied by the primary colors red, blue, and yellow in adaptations of abstract compositions by the artist Mondrian to the perceived weight of the areas and the location of the perceived balance centers of the compositions. Their stimuli consisted of the five color variations of each of six original Mondrian works created by changing the colors in the three different-sized rectangular areas in each composition resulting in all possible spatial arrangements of color for each original. Locher et al. found that for both art-trained and untrained viewers, the perceived weight of a color, especially red and yellow varied as a function of the size of the area it occupied. Participants perceived shifts in the location of the balance centers between the originals and their altered versions. Furthermore, participants were in strong agreement as to the location of the perceived balance centers of the original compositions which were typically seen near the geometric centers of the pictorial fields. These findings demonstrate the existence of a color-area-weight relationship among color triads in abstract compositions.

Typically, paintings contain more than two or three colors. In more structurally complex art works the weight of each color component is a function of the relationship between all of the compositional colors and the areas they occupy, that is, to the colorimetric properties of the pictorial field as a whole. These art works have three centers: a geometric center, a barycenter, and the perceived balance center. The geometric center is the point at which the vertical and horizontal axes of the pictorial field intersect. The barycenter is the location of the "center of gravity" of the pictorial field determined by the distribution of perceptual weights within the field. The third center is the perceived balance center, which is the center of the pictorial field as perceived by a viewer. The purpose of the present study was to compare the location of the colorimetric barycenter of paintings to their geometric centers. We computed the location of the barycenter of a large number of paintings representing a variety of compositional genres as explained below and compared these graphically with the geometric centers of the art works. It was anticipated that artists' manipulation of a color palette and their spatial control of color within a composition would result in the location of the colorimetric barycenter corresponding to the geometric center and that this would be the case for both abstract and representational paintings.

METHOD

The Colorimetric Barycenter Methodology

Firstov, Firstov, and Voloshinov (2005) define the *colorimetric barycenter* as the transformation of the Cartesian product of Im and F to W

$$\mathrm{Im} \times \mathrm{F} \rightarrow \mathrm{W}$$

where Im is the image surface (Euclidean area); F is the color space (one-dimensional for black-and-white images and three-dimensional for colored images according to the RGB or CIELAB color space models); and W is the interval of real number [0, 1]. According to this transformation, every pictorial image point (depending on its color) is brought to conformity with a non-negative number from W multitude, which is designated the “colorimetric mass” of this point.

Since bright colors are perceived as “light” and dark ones as “heavy” (e.g., Alexander & Shansky, 1976), we assign a minimum weight of 0 to white color points; the values for the weights of grey points increase as their color approaches black, and a weight equal to a unit (i.e., 1) to black color points. The colorimetric barycenter of the picture can then be calculated on the basis of the well-known mechanics formulas:

$$x_0 = \frac{1}{m}\sum_{j=1}^{n}\sum_{i=1}^{k} x_i m_{ij}; \quad y_0 = \frac{1}{m}\sum_{i=1}^{k}\sum_{j=1}^{n} y_j m_{ij},$$

where $(x_i;\ y_j)$ are pixel coordinates with indexes $i;j$ and colorimetric mass m_{ij} $(i = \overline{1;k},\ j = \overline{1;n})$, k is the number of columns on the picture; n is the number of lines on the picture; $m = \sum_{i=1}^{k}\sum_{j=1}^{n} m_{ij}$ is the colorimetric mass of the picture; $[(x;y);(R;\ G;\ B)] \rightarrow R+G+B = m(x;y)$ is the colorimetric mass of $(x;y)$ pixel; and $R,\ G,\ B$ are the color coordinates in the RGB color space model.

In the case of CIELAB model application, colorimetric mass is defined by the amount of chromatic thresholds (dE) between the given color and the color white. The data computed applying a CIELAB model are analogous to the data obtained utilizing the RGB model.

Stimuli

The art stimuli were reproductions of 1332 paintings by renowned Russian artists consisting of four categories of art works. One group included the 1174 works on a CD entitled *Modern Russian Art* (available at http://eng.nmg.ru) which is devoted to the art of modern Russian painters of the late 20th century. A second set consisted of 30 landscapes created by Russian painters of the late 19th and early 20th centuries. Seventy portraits by Russian artists working in the early 20th century constituted the third set and 58 non-representational pictures of Russian avant-garde painters of the early 20th century made up the fourth set of art stimuli. Images of the paintings in the last three groups were scanned from high quality color reproductions in art books. A variety of compositions was selected for inclusion in these three sets in terms of their structural organizations.

Procedure

To compare the location of the barycenters of paintings within and between each category of art works, all paintings were brought to a normal form, mathematically speaking. That is, for each painting, its width was divided by its width, and its height was divided by its height, resulting in a square image with sides equal to 1. In other words, barycenters were computed using relative or non-dimensional coordinates.

The location of the barycenter in relative coordinates was computed for each of the 1332 art stimuli. Figure 1 shows the locations of the barycenters for the ensemble of paintings included in each of the four categories of works described above. In each plot, the black lines are the horizontal and vertical symmetry axes of the normal form of the paintings, the black dots indicate the location of the barycenter of one or more paintings, and the black circle indicates the location of the average value of the barycenters for the ensemble. The number of black dots in each ensemble is less than the number of pictures included in the group because the barycenters for several paintings were positioned at the same locations and others coincided with the area covered by the black circle.

RESULTS AND DISCUSSION

The purpose of the present study was to compare the location of the colorimetric barycenter of a large number of paintings of different genres to their geometric centers. It was anticipated that artists' spatial control of color within a composition would result in the location of its colorimetric barycenter corresponding to its geometric center. As seen in Figure 1, the distributions of barycenters for all compositions are located very near the geometric center of the compositions and there is little scatter of the data points about the geometric centers relative to the entire pictorial field depicted in normal form. This indicates that "colorimetric mass" is evenly distributed on the canvas surfaces for both the representational and abstract paintings studied and supports the view of Arnheim (1974) and others that artists are intuitively sensitive to this component of pictorial balance as they create the structural organization of a composition. Our observations are also consistent with results of studies by Locher et al. (1998, 2001) described above which demonstrated that the barycenters of black-on-white designs created by individuals with training in the visual arts were closely aligned with the geometric center of the pictorial field.

The distribution of colorimetric barycenters for the collection of 1174 paintings representing a variety of artistic styles depicted in Figure 1D is clustered about the geometric center and has the form of a vertically posed ellipse with a greater number of centers located below the horizontal axis. Specifically, 346 centers are located above the horizontal axis and 825 below it (3 are located on the axis); the difference is significant (Binomial test, $z = 13.98$, $p < .001$). Additionally, there are 4 barycenters above and 26 below the horizontal axis for the landscapes as depicted in Figure 1A, and 20 centers above and 50 below the horizontal axis for the portraits in Figure 1B. These differences are also significant, $z = 3.85$, $p < .001$ and $z = 3.47$, $p < .001$, respectively. There are 24 centers above and 33 below the horizontal axis for the non-representational works depicted in Figure 1C, a non-significant difference, $z = 1.06$. We speculate that the distributions for Figures

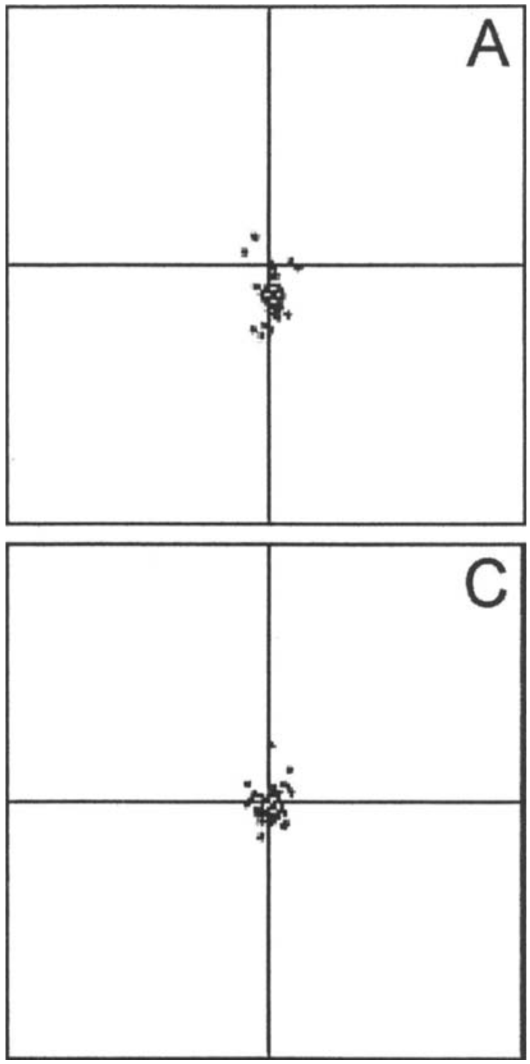

Figure 1. (A) The colorimetric barycenter ensemble of 30 landscapes by Russian painters of the late 19th and early 20th centuries; (B) the colorimetric barycenter ensemble of 70 portraits by Russian painters of the early 20th century; (C) the colorimetric barycenter ensemble of 58 non-representational works by Russian avant-garde painters of the early 20th century, and (D) the colorimetric barycenter ensemble of 1174 pictures of contemporary Russian painters of the late 20th century. In each plot the black lines are the horizontal and vertical symmetry axes of the normal form of the paintings, the black dots indicate the location of the barycenter of one or more paintings, and the black circle indicates the average value of the barycenters for the ensemble.

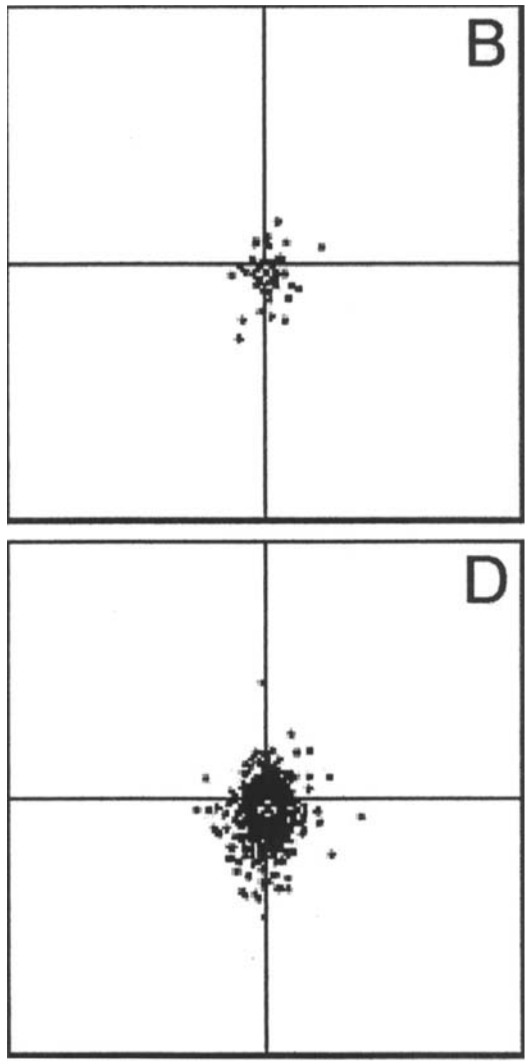

Figure 1. (Cont'd.)

1A, 1B, and 1D may reflect the assertion by art theoreticians (e.g., Arnheim, 1974, 1988) that, due to the force of gravity dominating our world, the anisotropic distribution of physical weight within a picture is a major global display feature that contributes to the balance and dynamic quality of a composition. Visually, objects in a picture or design carry more weight when placed "higher up" in a composition; they are perceived as an active force that presses perception downward. To create an equilibrium between visual forces about the horizontal axis of a painting artists often place more structural weight in the lower portion of a composition than in the upper region. This is the case regardless of whether the content of a composition is abstract or representational, although the effect appears to be more pronounced for realistic subject matter. The fact that a greater number of colorimetric barycenters are located below the geometric center of the compositions as seen in Figures 1A, 1B, and 1D may reflect the anisotropic distribution of color within the paintings by the artists to achieve pictorial balance.

In conclusion, results of the present study demonstrate the power of the center of a pictorial field to function as an "anchor" or balancing point about which artists exert spatial control of color among all of the compositional colors and the areas they occupy within the pictorial field as a whole. Left unanswered by the present study is the extent to which the colorimetric barycenter of a painting corresponds to the perceived balance center of that work. Finally, as Kreitler and Kreitler (1972) point out, the consideration of colors in a painting by themselves ignores the object references and connotations of colors. We acknowledge this limitation of our study and the need for additional research which takes these factors into consideration so that a more comprehensive understanding of the contribution of color to pictorial balance can be achieved.

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