David Corwin, MD dcorwin@dcorwin.org

Luminance balance in Pictorial composition: determining pictorial weight in the visual system

Introduction

Pictorial composition, the arrangement of forms in a painting so as to create feelings of unity, harmony and balance, has been an important concept in painting and aesthetics. The scientific approach to art and visual design started in the 19th century with critics such as John Ruskin and Charles Blanc who felt that although one could not give rules of good pictorial composition; there were certain laws or principles that should be followed. (Locher H, 2000). Through observations of pictures, it seems natural to compare balance in a picture to the balance of a physical object. A large object on one side close to the center can seem balanced by a smaller object farther from the center on the other side. (McManus 1985). Denman Ross, a professor of design at Harvard proposed a theoretical way of assigning weight, size, harmony, rhythm to pictorial units for which of necessity simple design elements were used (Ross, 1907 p 4). At the same time Alfred Poore, a painter, wrote an influential book in which he asserted: "A picture should be able to hang from its exact centre. Imperfect composition inflicts upon the beholder the duty of accommodating his head to the false angle of the picture". Masses, objects, colors, etc were felt as if they exerted a visual force and the balancing of these "visual forces" around the center would lead to an aesthetically satisfying painting. (Poore, 1903 p. 35)

In a somewhat analogous fashion Wassily Kandinsky (1926), an artist, described the feeling of visual forces evoked by points, lines and forms in a composition although he did not insist on the "mathematical" balancing of these visual forces. Subsequently Rudolf Arnheim, a gestalt psychologist, restating much of what Ross wrote, thought that pictorial balance was the result of these visual forces and associated them with a physiological counterpart. (Arnheim 1974, p.17) He proposed without much empirical basis that an aesthetically satisfying picture has a center-of-mass along either the horizontal, vertical or diagonal axes although this was never mentioned in his subsequent books. Pinkerton (1974) could find no correlation between colors, luminance and apparent weight when not viewed in a picture so that this is a pure pictorial phenomenon.

For the last fifty odd years it has been primarily gestalt psychologists who have been interested in this phenomenon as an important aspect of pictorial composition and who examined Arnheim's assertions. McManus summarized the results of this research as: "if a single conclusion were to be drawn from these studies, it is perhaps that empirical studies either use extremely simple, synthetic images, and hence risk being accused of not truly being about aesthetic judgments, or they alternatively use complex natural or artistic images, and run the risk of no clear conclusions being possible" (McManus, Zhou et al 2011 p. 334 This was also the conclusion of Gershoni 2011. They did a comprehensive study using Japanese calligraphic images that were presumed to be balanced and obtained contradictory result concluding that perceived balance is "not necessarily a statistical quality of an image."

The author approached the problem of pictorial balance from another direction. Instead of using the untrained "eye" and paintings of fine art that were accepted as "balanced," observations of painters creating paintings were used. This was one of the ways that Gustav Fechner proposed as a means of examining the problem. (Fechner 1871) Some painters have a manner of conceiving a properly

composed picture which is almost never discussed unless an actual picture is being viewed. When a picture is visually successful, the viewer can only say something to the effect of "that's it" or "you've got it." It has no name or metaphorical description. Moreover, the pictorial effect is illusive and can disappear if the painting, its illumination, or the viewing position is changed. It is not explicitly said that such a painting is "balanced," but the effect gives the painting the same qualities attributed to such a painting: harmony and unity. This creates a paradox in which a pictorial sensation observed by a certain number of painters but not all cannot be discussed for lack of a vocabulary and tradition. It has been forgotten by 20th century art critics and training. Given that the reader is being informed of a visual effect that they most probably have never been aware of, it is important to give some historical information concerning it.

Roger de Piles, a French artist and critic at the beginning of the 18th century described a surface effect in some paintings of "lights and darks" that was spontaneous and intense permitting the viewer to gaze at the entire painting without focusing on any particular form. This effect was said to be both immediate as well as prolonged during the entire viewing experience. He thought it was the most important aesthetic effect of a painting (Puttfarken 1985 p. 38). His ideas were well known throughout the 18th and 19th century; Eugene Delacroix (p. 63) in the 1830's, well aware of de Piles' writings, noted:

> There is a feeling that can only be evoked by painting. Nothing else can give an idea of it. It is the result of a special arrangement of colors, lights and darks, etc. what one might call the music of the painting. Finding yourself at too great a distance to know what is depicted, you are taken by this magical combination… This is the true superiority of painting over other art forms; it goes directly to the most intimate part of the soul. (translation by author)

Later, Kandinsky describes it, but without the knowledge of de Piles' observations which would have permitted him to understand his sensations. He drew the conclusion that it resulted from the absence of recognizable objects as did subsequent biographers:

> It was the hour of approaching dusk. I returned home … when suddenly I saw an indescribably beautiful picture, imbibed by an inner glow. First I hesitated, then I quickly approached this mysterious picture, on which I saw nothing but shapes and colors, and the contents of which I could not understand. I immediately found the key to the puzzle: it was a picture painted by me, leaning against the wall, standing on its side. The next day, when there was daylight, I tried to get yesterday's impression of the painting. However, I only succeeded half-ways: on its side too, I constantly recognized the objects and the fine finish of dusk was lacking I now knew fully well, that the object [objective form] harms my paintings. Kandinsky. p. 368

Through the process of creation (and destruction) this writer, a painter, noted that this effect was created when the two upper quadrants and the two lower quadrants seemed to be balanced with the upper half somewhat darker than the lower half. Using computer images that exhibited the effect, it was discovered that the visual summation process was simple quadrant luminance and not a center-of-mass calculation as had been so frequently proposed. Luminance ratios explain the elusiveness of the effect, depending on the lighting (time of day or change of illumination as noted by Kandinsky) and the position of the viewer with respect to the painting. It also explains the observation by painters that any slight change of the painting will destroy the effect. A picture exhibiting this effect will be said to be

pictorially coherent. Imbalance is being used for a non-coherent state as "uncoherent" is not a word, incoherent means something different, and non-coherent can be awkward.

Study objective: to show that the visual system determines the balance of an image using quadrant luminance

The author maintains the following:

A pictorially coherent painting is a distinct visual state for some individuals. Relative states of imbalance are detectable but do not have clear delineations. When seen at eye level it has equally luminous upper right and left quadrants and lower right and left quadrants. The upper half must be 1.07 ± 0.03 less luminous (darker) than the lower half. The calculation of luminance in a digital painting is determined with the image in the RGB color mode by the Photoshop CS6 luminance function or the rgbtogray function in Matlab (black being 1 and pure white being 255). This Matlab function has been shown to provide the most satisfactory perceptual conversion to a black and white image (Cadik 2009). Both give equivalent luminance values. This is called the luminance balance criteria for a painting when the center is viewed at eye level.

The visual system's determination of balance is a low level visual function concerned with only object borders so that the frame can be viewed as part of the painting. Objectively it was realized that if a painting is in a white frame and the whole is seen against a black ground, the eye sees the white frame as part of the painting with respect to visual balance.

The visual balancing point of any given rectangular picture at eye level is the sum of four vectors defined in the following manner: Each quadrant's luminance is considered to be a vector with a direction emanating from the geometric center of the picture towards the quadrant's corner and a value equal to its luminance. For the upper quadrants the vertical coordinate (y) of each vector is modified by a factor of 1.07 conforming to the luminance balance criteria. For a perfectly balanced image the sum of these four vectors would be approximately zero. For an unbalanced image, the distance of imbalance would correspond to the absolute distance of this point from the center. figure 1

Imbalance $=\sqrt{(XULQ + \mathrm{XURQ} + \mathrm{XLLQ} + \mathrm{XLRQ})\text{^}2 + (\mathrm{YULQ} + \mathrm{YURQ} + \mathrm{YLLQ} + \mathrm{YLRQ})\text{^}2)}$

TO reviewers XULQ should read X_{ULQ} but this cannot be done (easily) in Word.

Where X_{URQ} and Y_{ULQ} are the x and y values of the luminance of the upper right quadrant as in figure 1

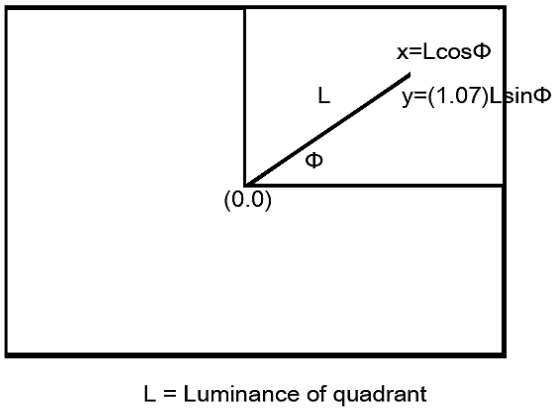


Figure 1 The Calculation of X_{URQ} and Y_{URQ}

The study is designed to show that, given this definition of balance and the assumption that the balance of these pictures includes the frame, a coherent picture is distinctive.

Studies No. 1 and 2

Method

To eliminate all variables except the property of balance, a coherent framed image is compared with the same image framed differently so as to make the second picture unbalanced. A sensitive observer looking at the central picture would see the effect turn on or off as the frame changes. Any perceived difference would be ascribed to the overall state of balance. This is not absolutely true as any picture framer will attest, but in the context of this study the picture framer effect is negligible. This effect is caused by the smaller lower border giving the feeling that the eye can enter the central image easier while a larger lower border gives the feeling that the image is farther away (Puttfarken 2000 p. 3, 24). For pairs in which both pictures are unbalanced, it was initially presumed that subjects would find the pictures to be identical. In the first case of balanced/unbalanced pairs a response of "different" would be labeled correct while in the second case a response of "same" would be identified as correct.

Subjects viewed the images on a black iPad 3 using an app ColorTrue™ calibrated with a "colormunki DISPLAY™." These images maintain the same dimensional ratio and their size was 5.7 x 7.4 inches or somewhat less on the iPad. The iPad permitted the viewing of the images parallel to the line of vision in a situation where a monitor would be inconvenient. There was limited control of reflections that could render a coherent image unbalanced. iPad models later than iPad 4 cannot be used due to a change in the ColorTrue™ application. The native "photo" application on a Windows 10 computer or an apple photo application which displays images on a black ground can be used with a calibrated monitor.

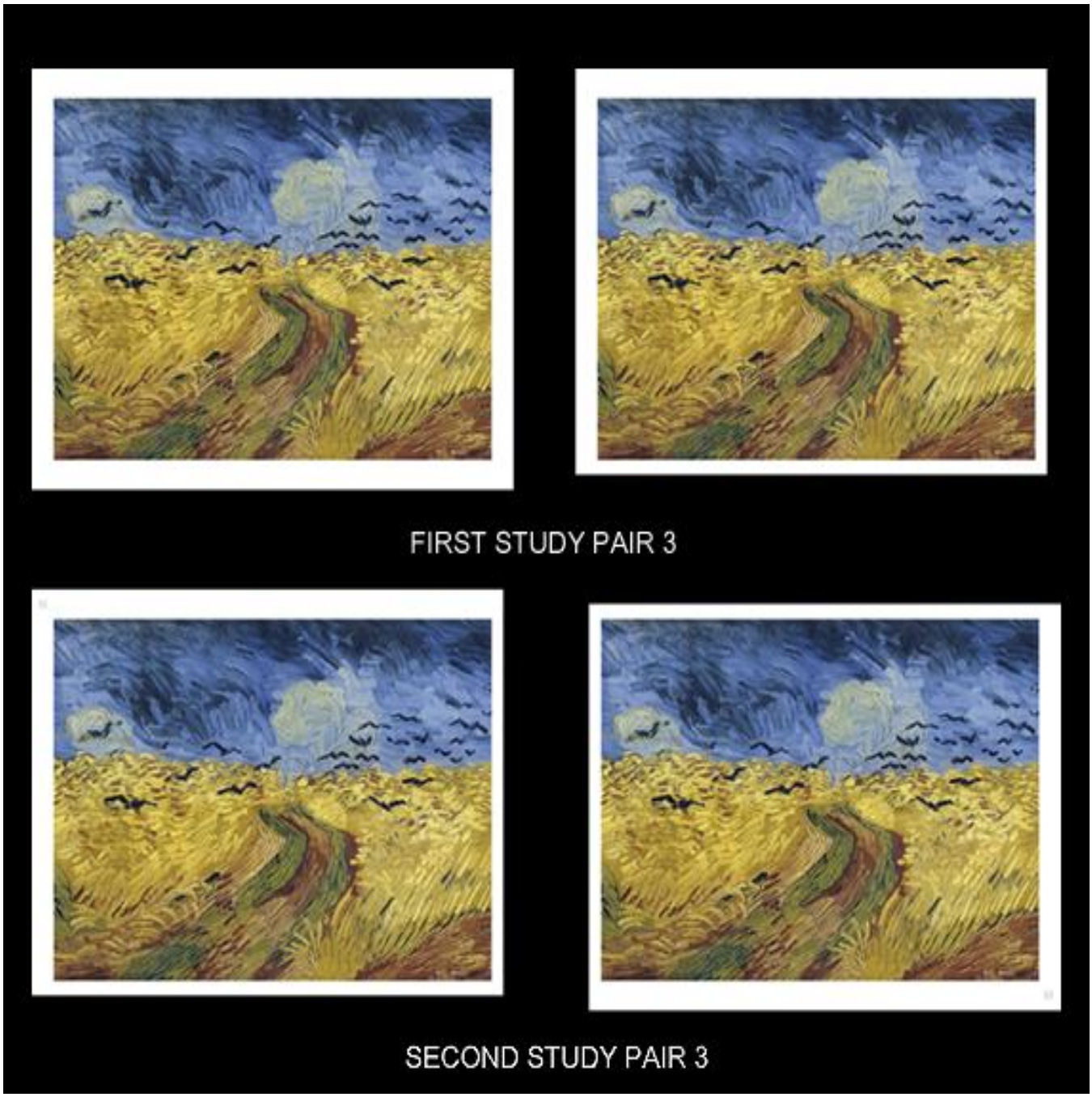
Image Preparation

The two studies were done using the same ten pictures (Image 1) but with different pairs of frames and modifications of the pictures to achieve balance as per the needs of the respective study. In the first

study four different 7.3x10” images were placed in 8.5x11” frames and the quadrants of the images were modified to make the framed image coherent. For each framed image parts of two sides were replaced with black bars to make the image unbalanced (changing the quadrant balancing) while maintaining positional constancy on a monitor. Five other images in white frames were unbalanced to begin with and when these frames were altered they remained unbalanced. For image pair 3 the procedure was reversed, the asymmetric framed image was balanced and its pair was a symmetric but luminant unbalanced framed image

The second study used five 7.3x10” images in asymmetrical frames which were adjusted to be coherent. The unbalanced variants were made by flipping the white asymmetric border. With Image 3 the asymmetric bordered image was coherent and the symmetric variant was unbalanced. Five other images in an asymmetric border were unbalanced with unbalanced variants made by similarly flipping the frame.. When the balanced image is seen on a monitor and then replaced by the unbalanced variant, only the border changes while the central image remains in place. Images in the RGB mode were balanced with Photoshop’s luminance measurement or Matlab 2017’s rgb2lab function. Image pair 3 of both studies are shown in IMAGE 2 as they would be seen although seen sequentially.
(**provided the monitor is calibrated and the image is seen as the original jpg or tif file**)

IMAGE 2 (Pair 3 of both studies)



The luminance values of the pictures' quadrants without the black borders as determined by Photoshop™ of the two studies as they would be seen by subjects are listed in table 1.

Procedure

Each study consisted of a subjects seeing a picture pair sequentially and being asked to say whether the two central images appeared to be the same or different. There were ten pairs of pictures: Five in which one was coherent and one unbalance, and five in which both pictures were unbalanced. Prior to beginning the study the subjects were shown sample pictures, and the difference in framing was pointed out. They were told to concentrate on the internal image and were told that they were identical in each pair. They were also told that in some image pairs, they might appear different to some people and in other image pairs it was expected that they would appear identical to everyone. The analogy of a monophonic and stereophonic recording was used to explain how they could see a difference in identical pictures. They could go back and forth between an image pair but viewing partial images was not permitted. In the first study if they saw a difference, they were asked to describe it if possible but were told that it might not be explainable.

Subjects were predominantly artists drawn from people associated with an art school. There were no requirements other than a willingness to participate and follow directions to carefully view the central image. Subjects were excluded who did not follow directions by rapidly concluding that all were identical or by insisting that every image pair was different because the frames were different. The first study consisted of 45 subjects, and in the second study 39 subjects participated. With respect to the above observation concerning the difference between a narrow and wide lower border, of the roughly two hundred people who participated in the preliminary and final studies, only one mentioned that it was easier for the eye to enter the picture in one rather than the other of a pair. Most of the subjects in preliminary studies drawn from the general population or college students would promptly say that the central images were the same. It is not known what they would say if paid to concentrate on the test.

The study was done with informed consent and subject confidentiality in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki).

Results

Of the included 45 subjects in the first study and 39 subjects in the second study, differences between identical images were seen in picture pairs that were both balanced and unbalanced. The most commonly described difference was between the intensity or color hue. Some paintings were thought to be more vibrant or have more depth. Many subjects could clearly see a difference but were unable to describe the reason. A difference observed in a balanced/unbalanced pair was marked “correct” and “no difference” or same in an unbalanced /unbalanced pair was also marked correct.

Table 2 shows the percent of correct and “same” identification for each image pair.

Table 3 shows the number of subjects and the number of images “correctly” identified for each study and the relative frequency of each group. For someone who did not see the effect, they would answer 5 out of 10 correctly i.e. all were the same. These results indicate that for this group of subjects it is probable that the effect had an influence on how they viewed the two images, but cannot be statistically proven as opposed to chance.

The degree of balance for each image was calculated as the sum of the four quadrants' luminance vectors according to the formula described above (figure 1) For each picture pair an average state of imbalance was calculated. This average state of imbalance was compared to the percent of subjects that answered either "correctly" or "same" for that image pair. The two studies were combined because they both relate to the same observation: average pair distance and observer's perceptions of "correct" or "same." The correlation between "same" and average degree of imbalance is F= 6.1 (two tail) p = 0.00037. The correlation between identifying "correct" and average degree of imbalance is F = 10.5 (two-tail) p = 0.00001 (table 4)

The results can be divided into two groups: the coherent pair group and the unbalanced pair group for both studies (see table 5). For the coherent group (images no. 1,3,5,7,8) the mean distance is 10.4 (standard deviation 3) and the mean percent of "same" answers is 0.597. While for the unbalanced group (image no. 2,4,6,9,10), the mean distance is 29.2 (standard deviation 9.5) and the percent of "same" answers is 0.753. Within the coherent or unbalanced groups there is no simple correlation between distance and answers. Picture pairs which are relatively balanced can be clearly distinguished from picture pairs that are much more poorly balanced.

The total correlation between answers and distance is significantly better (p .00001 vs .00037, p 0.02) with the "correct" results. These results include the coherent effect: the special effect of coherent images that improves the probability that subjects will see a difference which will result in a "correct" result. This indicates that the coherent effect is seen.

Study No. 3

It was previously stated that the pictorial coherent criteria included the upper half be darker by 1.07 ±.03. In order to determine the range of the ratio of the lower half to the upper half for an image to be seen as coherent, an 7.3 x 10" image in a 8.5 x 11" frame were modified progressive from a ratio of 1.01 to 1.3 with some repetition. (1.01 1.02, 1.02 1.03, 1.04, 1.07, 1.09, 1.10, 1.11, 1.11, 1.12, 1.13) This study had to be done last because the preceding studies were used to find participants who could see the effect. The images were viewed in no particular order with some duplication. This writer and two subjects participated.

Conclusions

Pictorial balance determination is a low level visual system function and is calculated using the luminance criteria. The subjects could determine a difference between pictures that had low degree of imbalance from those that have a higher degree of imbalance, and in the special case they can distinguish a coherent image or perfectly balanced one from a non-coherent one.

Coherence: description and explanation

Delacroix provides an aesthetic and psychological description of a coherent painting. For this writer there is the feeling that the eye can glide around the painting without fixating on the forms and can simultaneously gaze at the whole image. Slight unbalance interferes with this. This is the absolute sense

of coherence; a good partial effect cannot be simply described. This effect on eye movement is what is felt to distinguish coherency.

Although certain images meet the luminance balance criteria, they cannot be seen or are only weakly seen as coherent for the author because they have salient features such as geometric forms, equiluminant forms (forms that vibrate), or many scattered forms that cannot be seen as part of a few larger forms. The eye has difficulty ignoring the salient aspects and has to look at the forms. I do not think it is an either or process but changes gradually as the image becomes progressively unbalanced or changed by salient features. The study done with a more homogeneous group of unbalanced pairs and more subjects might show how finely the visual system can distinguish between degrees of imbalance.

A monotone red image meeting the luminance balance criteria does not appear coherent while the same monotone image in another color is seen as coherent. (IMAGE 3). An explanation for these observations is that the magnocellular visual system plays an important role in seeing the effect. This visual pathway is very sensitive to luminance, perceives the world with a low spatial frequency and is inhibited by red light (Livingstone 1984, Chapman 2004 Awasthi 2016,). Stimulation of the magnocellular pathway inhibits saccadic eye movements used in the normal viewing of pictures, and it is itself inhibited by these movements (Burr, 1994). The more a picture has these characteristics, the more it will be perceived as unbalanced. It would seem that pictorial balance is an aspect of a more general ability such as assessing the path and speed of moving objects or object rotation. Viewed in this way an object is reduced to a simple vector.

IMAGE 3 Monotone in green and red

Green image ratio 1.07 quadrants 127.00 127.06 135.75 135.75
Red image ratio 1.066 quadrants 153.45 153.74 163.58 163.90

While the idea of pictorial balance has been important among certain painters and critics, balance as coherence has also been rejected or just not recognized by the avant-garde artistic community as the Kandinsky anecdote illustrates. Hans Hofmann an influential artist and teacher during the 1940's and 50's had a system of composition in which a suggestion of depth and movement was to be created by contrasts of color, texture and form so as to create what he characterized as a "push pull" effect. For Hoffmann "if a plastic result is to be achieved…two opposing pitfalls must be avoided: on the one hand a flatness which is passive and empty, and on the other a depth which is imitative and sterile." (Seitz 1962 p 27). Hoffmann wanted to use visual manipulation to create the illusion of movement or animation on the canvas which is what coherency does. Clement Greenberg (1982) a major art critic of mid-century modernism thought that the driving force of avant-garde painting (and art in general) "for the last hundred-odd years" was the steady self-criticism of all classical attributes until it had arrived at pictorial attributes fundamental to painting: the totally flat image. One of these rejected classical attributes was coherency although it is ironic that coherency is a fundamental property of a circumscribed form. It has been the experience of this writer that poor pictorial balance can be a positive aesthetic attribute in the fine arts community while a coherent painting can be a marker of what is not contemporary. In this sense it was not with abstraction but coherency that modernism made a definitive break in the tradition of painting.

Coherency and the feelings of unity and harmony that it provides is only one aspect of the aesthetic qualities of a painting. For the writer it is one of six criteria for quality which include the feeling of poetry or lyricism, complexity, the appearance of authorial intelligence, the visual resolution of contradictions in life, and a particular feeling of surprise that may or may not be related to coherence.

Summary

The visual system assesses the balance of a painting by a formula using the weighted values of the luminance of the four quadrants. It is often interpreted as a center-of-mass balancing effect related to tone, color, forms and lines. When the center of luminance balance coincides with the geometric center, a special effect is seen by some people. This effect called coherence although clearly perceived by some with something sometimes approaching awe or surprise gives to many feelings of unity and harmony to the painting. Coherence is an important concept in art history, the art of painters, the philosophy of aesthetics, the psychology of aesthetics, and the neurophysiology of vision.

BIBLIOGRAPHY

Arnheim R, 1974 *Art and Visual Perception* University of California Press Berkeley

Arnheim R, 1984 *The Power of the Center*, University of California Press, Berkeley 1984

Awasthi B, Williams M A, Friedman J, 2016 Examining the role of red background in magnocellular contribution to face perception *PeerJ*. .doi:10.7717/peerj.1617

Maillet A *The Claude Glass: Use and Meaning of the Black Mirror in Western Art* Zone Books 2009

Burr D C, Morrone M. C, Ross J. 1994 Selective suppression of the magnocellular visual pathway during saccadic eye movements. *Nature*, **371**, 511 - 513

Cadik M, 2009 Perceptual evaluation of color-to-grayscale image conversions *Computer Graphic Forum* **27** 1745–1745 doi:10.1111/j.1467-8659.2008.01319.x J

Chapman C, Hoag R, Giaschi D 2004 The effect of disrupting the human magnocellular pathway on global motion perception *Vision Research* **44-2:** 2551-2557**,** https://doi.org/10.1016/j.visres.2004.06.003

Chase C, Arash A, Kelly C, Monfette S, Kinsey K 2003 Can the magnocellular pathway read? *Vision Research* **43**:1211-1222,

Delacroix E, 1923 Œvres Littéraires. Études Esthétiques 4th ed G. Crés & Cie, Paris

Gershoni 2011 Measuring pictorial balance perception at first glance using Japanese calligraphy i-Perception **2:**508–527 doi:10.1068/i0472aap

Greenberg C. "Modernist Painting" 1982 in *Modern Art and Modernism: A Critical Anthology* Esthetics Contemporary Harrison C and Franscina F (ed) 1982 Sage Publications (also http://www.yorku.ca/yamlau/readings/greenberg_modernistPainting.pdf)

Fechner, G *Vorschule der Aesthetik* 1876 Breitkopf & Härtel Leipzig

Kandinsky, Wassily, 1866-1944; Dearstyne, Howard, tr; Rebay, Hilla, 1890-1967, ed. Point and line to plane : contribution to the analysis of the pictorial elements. New York : Solomon R. Guggenheim Foundation. P. 118

Kandinsky Complete Writings on Art vol 1, Lindsay amd Vergo (ed.) . 369 G.K. Hall and co. Boston 1982

Livingstone MS, Hubel DH, 1984 Anatomy and physiology of a color system in the primate visual cortex. *J Neurosci.* **4-1**:309-56

Locher Hubert 'Towards a Science of Art: the Concept of 'Pure Composition" in Nineteenth- and Twentieth century Art Theory' in *Pictorial Composition from Medieval to Modern Art* Taylor P and Quiviger F (ed.) Warburg Institute, London 2000

McManus I C Stover K Kim D 2011 Arnheim's Gestalt theory of visual balance *i-Perception* **2**:615-647

McManus IC Zhouo FA l'Anson S Waterfield L Stover K Cook R 2011 The psychometrics of photographic cropping Perception 40 332-357

Pinkerton E, Humphrey N 1974 The apparent heaviness of colours *Nature* **250:**164-165

Poore Henry Rankin 1903 *Pictorial Composition and the Critical Judgment of Pictures* New York

Puttfarken, T 1985 *Roger de Piles' Theory of Art*, Yale University Press New Haven,

Puttfarken T 2000 *The Discovery of Pictorial Composition* Yale University Press New Haven

Ross, Denman 1901, *Proceedings of the American Academy of Arts and Sciences*, 36:21, p 357-374

Ross, Denman 1907 *A Theory of Pure Design* Houghton, Mifflin and Co. Boston, 1907

Seitz, W C *Hans Hofmann with selected writings by the artist* Museum of Modern Art New York 1963 https://www.moma.org/documents/moma_catalogue_3439_300010626.pdf

Wright B 1962 The Influence of hue, lightness and saturation on apparent warmth and weight *Am J Psychology* **75-2:**232-241