Pictorial balance is a bottom-up aesthetic property mediated by eye movements. A model of a primitive visual operating system explains balance and visual properties of pictures

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Abstract

The concept of pictorial balance originated at the beginning of the 20th century to explain why some paintings evoke feelings of unity and harmony. This concept had never been mentioned in previous writings of the last 500 years and has not been shown to be true. There is an unnamed pictorial effect observed by artists and described by a critic Roger de Piles in the 17th century that induces feelings of unity and harmony. It was thought that these pictures are perfectly balanced. Computer models were created and found to have bilateral quadrant symmetry with a lighter lower half by ~1.07. It was also observed that with respect to low-level balance the visual system sees only luminance, not objects. Two different methods were used to calculate balance. A study was done in which observers, mostly painters or people who like to look carefully at pictures, viewed identical pictures differing only by their state of balance. It was shown that high averaged unbalanced pairs could be distinguished from low average unbalanced pairs and that using the second method, picture pairs can be distinguished according to their state of average balance. It is an algorithm that could represent moving organisms as rectangular images: the more balanced, the more likely it is coming towards the viewer and drawing the viewer's attention. It is proposed that neurons that determine balance are in the pretectal area of the midbrain, and a method is proposed to find the location of the pre-emotional, pre-cognitive aesthetic center for pictures and perhaps all art.

Introduction

Pictures, bounded flat images, correspond to nothing found in nature or mental imagery. This includes the borderless images in prehistoric caves[1]. They are a very recent invention requiring the technology to create flat surfaces (maybe the fourth millennium BC). They differ from images without borders in that borders evoke the percept of balance: the parts relate to both the center and the borders[2]. Balance is both a bottom-up percept and a top-down aesthetic concept taught in schools. This paper is concerned with the bottom up perception of balance – the pre-emotional and pre-cognitive pathway from the retina to the primary visual cortex as Molnar postulated[3].

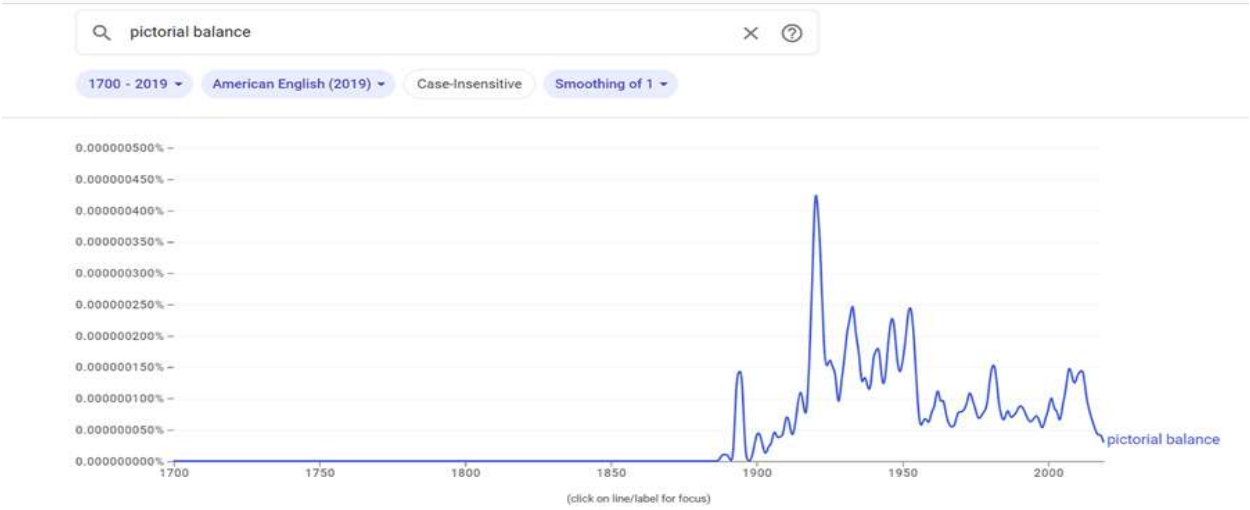
It has been stated that: "for centuries artists and writers on Western art have asserted that balance is the primary design principle for unifying structural elements of a composition into a cohesive narrative statement." A picture is considered balanced "if all its elements are arranged in such a way that their perceptual forces are in equilibrium about a fulcrum and if the fulcrum coincides with the center of the picture[4]." Objects, size, color, intrinsic interest, positions and apparent

depth have been proposed as contributing to the aesthetic pictorial qualities of unity and harmony if they are balanced around the geometric center as calculated by a center of mass type of equation[2,4-6]. Rather than being a timeless observation, it is only a late 19th century concept that corresponds to a general attempt at that time to apply science to painting and design. Poore, a painter, was one of the earliest promoters of this. However, he was most likely trying to explain the effect of bottom-up balance that I discuss in this paper in that he wrote:

> The whole of the pictorial interest may be on one side of a picture and the other side be practically useless as far as picturesqueness (sic) or story-telling opportunity is concerned, but which finds its reason for existing in the balance, and that alone.

Nothing in this "useless" side has the pictorial qualities described above, but for him they create in a particular picture a feeling that he calls balance[5]. There have been a number of recent studies that have tried to confirm this concept of balance without success[7-9]. H. Locher and T. Puttfarken give comprehensive discussions of European theories of pictorial aesthetics between the 14th and the late 19th century in which balance is not mentioned[10,11]. The judgment of balance is inherently a top-down idea taught in schools. A Google ngram search for "pictorial balance" gives a good idea of this. While it only includes books scanned by Google it exemplifies the above (see figure 1).

Figure 1. The frequency per year that pictorial balance was mentioned in books as scanned by Google by year



Balance has been thought to direct the eye and other than top-down direction, the force that strongly influences eye movement is salience. A sequence of saccades can be predicted through calculations based on the most salient features of surrounding areas, and this can be correlated with eye tracking[12-14]. There have also been studies that tried to show the more subtle effect of balance. Locher and Nodine compared eye movements in pictures that were thought to be balanced with variations of these pictures. They found that trained observers had more diverse and fewer specific exploratory movements in the more balanced compositions than untrained observers. On the other hand, Buswell could find no difference between the two groups. The duration of fixations and the length of saccades are usually discussed in top-down cognitive

terms of subject comprehension or artistic judgment unrelated to balance[15-19]. The concept of balance presented here does have an effect on eye movements and attention will be discussed below.

In order to understand and measure bottom-up balance one must start with a picture that exhibits the sensation of perfect balance. Balance has been used to explain the feelings of pictorial unity and harmony, and this corresponds to an obscure effect observed by painters that does just that. There is no name or metaphorical description for the percept evoked by these pictures other than to say that they exhibit the aforementioned unnamed effect. It is usually only discussed in art schools when standing before such a picture and then in vague terms. The unexpected change in a painting from being remarkably unified and harmonious to something less so or the reverse is quite striking. It creates the feeling that the whole picture can be seen at one time; the gaze moves smoothly around without the need to concentrate on any pictorial element. There is a qualitative difference between a perfectly balanced and a somewhat unbalanced painting where the gaze is forced to go from one object to another.

From an historical perspective Roger de Piles, an 18th century French critic and painter first described arrangements of "lights and darks" in paintings creating an effect that is spontaneous and intense riveting the attention and giving the impression that the viewer could gaze at the entire painting without focusing on any particular form. He thought this was the primary aesthetic effect of a painting and was unrelated to the French Academy of Art's concern with how a painting should tell a story[11]. Cézanne apparently noted this. Indeed, his inability to describe this effect gives some of his conversations a cryptic quality[20]. Both Delacroix and Kandinsky give vivid descriptions of seeing paintings that exhibit it[11,21,22] (Addendum A).

To study this effect I created through experience from many years of painting, computer models of pictures that evoke it based on observations that it had to have bilateral luminance symmetry with a slightly darker upper half. Image analysis indicated that the percept was obtained when a picture, centered at eye level and parallel to the plane of vision, has bilateral quadrant luminance symmetry with the lower half being slightly more luminous by a factor of 1.07 ± ~0.03 (where luminance is measured from 1 to 255 with black being zero as measured by Photoshop© CR6). A perfectly balanced painting will be described as coherent; all others will be called unbalanced for the purpose of the first objective of the study.

There is a theoretical formula for balance which is derived from this and explains observations of a center-of-mass like effect: if a rectangular picture with bilateral quadrant luminance symmetry and a darker upper half is said to be perfectly balanced around the geometric center, then the standard formula for the center of mass of four connected objects can be used. In this formula quadrant luminance L_{xxQ} replaces the mass of each object and is located at the geometric center (center-of-mass) of the respective quadrant. For simplicity, the picture's center is at (0,0). L_{TOTAL} is taken as the average total luminance.

$$X = (X_{ULQ}L_{ULQ} + X_{URQ}L_{URQ} + X_{LLQ}L_{LLQ} + X_{LRQ}L_{LRQ})/L_{TOTAL}$$
$$Y = ((1.07)Y_{ULQ}L_{ULQ} + (1.07)Y_{URQ}L_{URQ} + Y_{LLQ}L_{LLQ} + Y_{LRQ}L_{LRQ})/L_{TOTAL}$$
$$L_{TOTAL} = (L_{ULQ} + L_{URQ} + L_{LLQ} + L_{LRQ})/4,$$
$$\text{Balance} = \sqrt{X^2 + Y^2} \text{ or a vector } \vec{L}\ (X,Y)$$

Y values of the upper quadrants are modified by 1.07 to account for the increased visual weight of the upper half. X_{XXQ} and Y_{XXQ} are the coordinates of the center of their respective quadrants, and L_{ABQ} is a quadrant's luminance. The equation can be expressed as an addition of four vectors $\vec{L} = (X, Y)$. Although this equation is precise for defining perfect balance, it is not clear whether it is true for states of imbalance. This will be called the Geometric method of determining balance.

Another way of calculating bottom-up balance is derived from the idea that it would have evolved from a primitive method for identifying and following moving organisms either illuminated from above or emitting their own light as is seen in the sea. They are defined as collections of luminous points that move together with respect to a ground. If one were to divide this into two equally luminous parts by a vertical line which is itself bisected horizontally by another line, the object is divided into four parts. Virtual lines parallel to the preceding ones are drawn enclosing the object to create a "picture." The luminance of the upper half would be arbitrarily decreased relative to the bottom half by a factor (~1/1.07 in humans) to account for light coming from above rendering the organism more balanced. The light energy is averaged over a quadrant allowing the formulation of vectors of luminance and the calculation of balance according to the Geometric method. This second method is called the Visual method of balance.

Balance is determined at a level where the visual system cannot distinguish a picture from its white frame. This was discovered by accident. On one occasion I printed out black and white pictures that were balanced. Due to an error of alignment some prints did not show the effect. Since the picture and the white framed picture were of very similar height to length ratios, both were balanced when printed correctly. Misalignment caused the total image both picture and frame to be unbalanced. I derived from this that with respect to balance all objects are defined only by luminosity. For example , this is not true for an LED picture framed in black on a white ground where black marks the end of the picture.

There are two effects conveyed by balance as I experience it: the intangible effort that I feel for the eye to move across the picture and the attention riveting feeling described as a feeling of unity and harmony. With a picture seen by reflected light, the two seem inseparable. However an LED picture is a poor conveyer of the attention riveting effect which is usually interpreted as the aesthetic effect while it maintains the effect on eye movements. The lack of this attention riveting effect in LED pictures correlates with the study of Bertamini et al. who noted that observers preferred a print reproduction to the same picture in a mirror or on a monitor and that they preferred the mirror view of the actual image to the image on an LED screen[23]. Locher et al. made similar observations[24]. The only difference between these three situations is that the light emitted from an LED screen is polarized. Misson and Anderson showed that polarized light alters luminance contrast perception[25]. This in some unknown manner interferes with the attention riveting aesthetic effect so that it cannot be measured using observer preference. However feelings evoked by the ease of movement are experienced allowing a performance based study to determine whether two identical pictures were the same or different with balance being the only difference. LED images had to be used to permit precise luminance determination and reproducibility under the conditions that were feasible. Printed pictures could not be shown to have the stated luminance properties under these conditions.

The first object of this study was to show that some people are able to see this state of perfect balance, pictorial coherence, by showing that they perceive a difference in two identical pictures differing only because one is perfectly balanced. The second objective is to show that one or both definitions of pictorial balance (Geometric and Visual) are valid by showing that the study group is able to distinguish fine degrees of pictorial imbalance as determined by one or both definitions.

Materials and Methods

Since a white framed picture is seen by the bottom-up visual system as one object while the top-down view sees it as a picture in an uninteresting frame, the comparison of a balanced picture with the identical but unbalanced picture can be done by a slight change of frame. When the change occurs, the picture remains in exactly the same place on the screen. If an observer compares carefully the two images and is able to disregard the frame, any perceived difference would be ascribed to the effect. It was presumed that the pairs of unbalanced pictures would be indistinguishable if the frame was disregarded because initially I did not think that observers could see degrees of imbalance. Balance cannot be perceived unless full attention is devoted to the picture. This eliminated many potential observers who did not do this. They would glance at the pictures and rapidly decide there were no differences. Observers were included in the analysis if they carefully inspected the pictures whether they saw any difference or not. It was noticed that painters and those interested in looking at pictures would observe carefully. Two studies were done using different frames.

Each study consisted of ten pairs of images: five, in which one of the images was perfectly balanced and the other unbalanced (balanced pairs), and five in which both were unbalanced (unbalanced pairs). Images were chosen because they seemed to have predominantly neutral content. They were prepared using Photoshop©. Quadrant image luminance can be changed in an unobtrusive and precise manner through the use of the level command on an irregular form in which the luminance is usually changed by no more than ±5 percent. The form is then moved around until the desired quadrant value is reached. The two studies differed only in using different sets of white borders. The three possible image and border combinations are in Fig. 1. Study I compared figure 2a with either 2b or 2c. Study 2 compared figures 1b with 1c. The observer viewed sequentially a picture with different frames on a color-calibrated iPad3 using the ColorTrue™ app and a Colorite™ calibration device. The observer viewed the iPad centered and parallel to the plane of vision at arm's length. The images on the iPad were approximately 5 x 6.75 inches. The pictures used for the studies are shown Fig. 3, and this is the order in which they were seen. Images 1,3,5,7, 8 were the balanced pairs. (all images are in the supplemental files with accompanying quadrant luminance data)

Fig. 3 The three possible image and border combinations: the black lines would not be seen on a black ground.

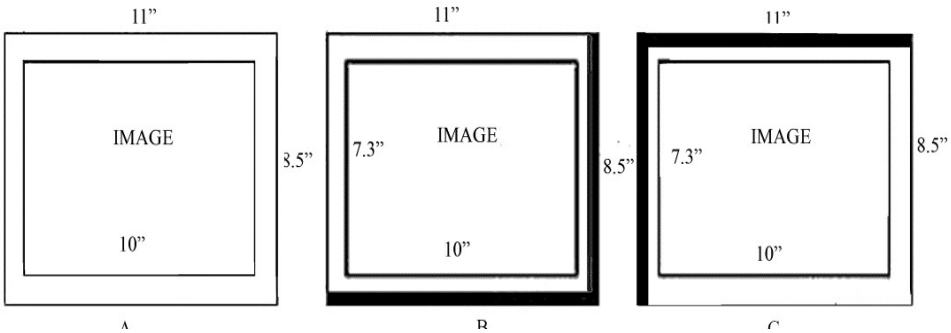


Figure 3 Pictures used in the study pairs

The observers gave their verbal consent to participate anonymously in a study about how people look at pictures. They were told that it would consist of looking carefully at ten pairs of pictures

and being asked whether the central images appeared to be the same or different while disregarding the frames. They were told that it was intended that some pairs might be seen as the same while others as different. No identifying information or medical history was obtained, and there was no attempt to eliminate observers who were color deficient, had cataracts or had impaired binocular vision. 45 observers were included in the first study and 39 observers in the second study. Observers were excluded if they did not follow the directions by either rapidly saying without careful examination that they could see no difference or by insisting that the frame change was the only difference. There were only four of the latter. For pairs in which both pictures are unbalanced, it was presumed that because of slight differences of imbalance, observers would find the pictures to be identical so that the response of "same" was considered correct. With the balanced pairs a response of "different" would be labeled correct indicating they had seen the effect.

Observers viewed the pictures sequentially on an iPad at arm's length while I sat slightly behind them. They were permitted, indeed encouraged, to hold the iPad themselves as long as it was maintained correctly centered and parallel to the plane of vision. There were no restrictions on the length of observation, and they could return to a previous image as much as they wanted. However, subjects were told that the difference if any was more in the way of a feeling and were discouraged from making point by point comparisons. The difference was described as analogous to that between monophonic and stereophonic music: same music but seems different.

Results and discussion

Four observers could identify all the balanced pairs correctly, and 5 observers made one error. (Table 1). Some subjects thought they saw differences in color. One thought the depth of field was different, and many saw differences but could not describe them. These results do not indicate that observers perceived the percept of perfect balance because the study is not sufficiently statistically powerful. It would require many more pairs to be statistically valid and is strongly influenced by the degree of imbalance in the unbalanced pictures. An easier and better way would be to ask the observers to observe how they moved their eyes around each picture and to state which one was easier or neither. I did this with one painter who seemed to have seen the effect in that he identified some of the balanced pairs and all of the unbalanced pairs correctly. He promptly identified all pictures correctly

Table 1 the number of observers answering correctly the 10 pairs in the study

1st study		2nd study	
Correct Responses	Observers	Correct Responses	Observers
10	3	10	1
9	2	9	3
8	2	8	1
7	4	7	6
6	13	6	9
5	12	5	11
4	7	4	5

3	1	3	1
2	1	2	2
Total	45		39

There is a correlation between the percent of pairs observed as different and the pair average distance (average imbalance) as calculated with the two methods (see table 2). The pairs can be divided into two groups based on balance: one in which the average state of imbalance is small (the balanced pairs), and the other where the average imbalance is large. The correlation for the Geometric determination between average pair imbalance and the percentage identified as different is: $r(18) = -0.676$, $p = 0.001$. The same correlation for the Visual determination is $r(18) = -0.757$, $p < 0.001$.

If one takes the average of the balanced pairs as one data point so as to avoid the statistical influence of the relatively large number of balance pairs and the ten unbalanced pairs as other data points, the Visual method has a correlation of $r(11) = -0.64$ $p = 0.046$. This would indicate that these subjects could perceive relative average balance across the pictures and not just between pairs with low and high average balance. There is no significant correlation with the Geometric method. These methods of determining low level pictorial balance are valid with the Visual method which incorporates the Geometric method being more accurate. Here having a variety of unbalanced pictures creates greater statistical power.

The ability to see pairs as different as a function of their average imbalance is true for the observers who were selected for their ability to follow the rules and who happened to be mostly painters. This correlates with studies showing that painters view pictures differently than untrained individuals [26-30]. Antes showed that fixation patterns distinguish painters from non-painters, and Koide et al using a prediction model of a saliency map showed that artists are less guided by local saliency than non-artists so that the effects of balance would be more manifest[27,32].

Table 2 Pair average distance and percent of observers who identified the pairs as different using both the Geometric method and Visual method of balance. The MATLAB™ code and corresponding pictures without black borders used to calculate the Visual balance is in the supplemental files.

BALANCED PAIRS	UNBALANCED PAIRS

		geometric distance average	visual average distance	% different		geometric average distance	visual average distance	% different
1st Study	1	8.81	8.66	0.49	2	11.39	15.72	0.36
	3	5.00	6.50	0.36	4	29.70	36.18	0.29
	5	6.97	11.06	0.44	6	26.36	30.90	0.33
	7	7.97	8.24	0.38	9	14.88	16.08	0.18
	8	8.08	8.05	0.44	10	25.98	39.02	0.11
2nd Study	1	2.92	11.15	0.41	2	14.67	19.60	0.28
	3	10.15	13.13	0.36	4	33.50	41.25	0.15
	5	7.35	9.92	0.44	6	30.09	29.15	0.38
	7	10.24	13.42	0.28	9	21.62	22.62	0.26
	8	15.96	15.76	0.44	10	38.19	42.68	0.13
average		8.34	10.59	0.40		24.64	29.32	0.25
StDev		3.48	2.88	0.06		8.83	10.35	0.10

The use of an iPad in different lighting environments was necessary to bring the study to the observers as no laboratory was available. Reflections from the iPad screen increased the number of false negatives, i.e. coherent pictures being seen as unbalanced as the reflections change quadrant luminance. It is highly unlikely that the reverse would be true. That observers saw unbalanced pairs as being different was contrary to expectations, and therefore could not be influenced by the examiner. A MacNemar test shows data validity $p < 001$.

Observations

The effect of balance on eye movements can only be determined with eye tracking by the viewing of the identical picture with two or more different states of imbalance. Measuring duration of fixation might confirm the observation that the more unbalanced the picture, the greater the tendency to linger at each fixation. Painters are trained to follow their eye as it moves around a picture, and it does require some training to look at pictures carefully. It can be said that most people are sensitive to balance if they look at pictures carefully because everyone finds looking at pictures in a museum fatiguing even if they remain in one room to eliminate fatigue from walking. Balance exerts an unaccustomed force on the eye muscles. Subjects constantly complained of it such that a study involving more than 12 pairs at one time is difficult.

Pictorial balance is extremely sensitive to small differences of quadrant luminance which explains its fugacity without precise viewing conditions (table 3). Changing the illuminating light spectrum or its height relative to the viewer destroys the effect. The light spectrum changes the relative RGB values and thus the luminance. With pictures in a studio even the drying of

paint in the following twelve hours creates a tonal change that is sufficiently to make it disappear. Given that not everyone can see the effect which is normally created through chance and even then is usually fleeting, and that there is no name for it, one can understand why it is not discussed in the 20th century literature.

A flat surface with no marks, i.e. one coated with an opaque layer of paint gradually modified so that the upper half is slightly darker, cannot be seen as coherent. Calculating backwards from the perceived balance i.e. discounting for the weighted upper half to the original viewed object, it would present itself as an object with four quadrants of equal luminance. There has to be some surface quality for this part of the visual system to recognize an object. It has been shown that forms in nature have a fractal quality, that fractal images have an aesthetic quality and that the visual system has evolved to respond to conditions of nature that are fractal[33.34, 35]. Therefore, it can be inferred that the part of the visual system that calculates balance is also most sensitive to fractal forms. The visual system is designed to work best in this fractal environment and not the world of manmade objects that are linear and uniform, causing the eye to jump from one form to another. To get an idea of this, the reader should look at their own eye movements when in a forest as opposed to a city scene (see comments on Cézanne in addendum A). Uniformly colored geometric forms with no fractal qualities and many equally prominent forms that cannot be combined conceptually detract from balance. Pair 2 is a good example of this. The eye is forced to go from form to form with slightly greater ease as balance improves. Geometric forms are usually solid unvarying colored forms that strongly attract the eye and do not exist in nature. It has been noted that binocular vision is necessary to view the percept.

Balance can be seen as a very early evolutionary method to follow a moving object. The visual system would identify the object by its vector and the virtual rectangle. Once done the visual system has "locked on" to it and can therefore distinguish it from all the other points of light. A complex object of whatever size is reduced to an ever changing vector and illusory rectangle. Even if it stops moving, the vector and rectangular halo would remain visible where it might otherwise blend in with the ground. Many different moving forms can be followed simultaneously with minimal computing power. The more balanced they appear; the more likely they are coming towards the viewer no matter their spatial location. This is a phylogenic explanation for why balance in pictures can command our attention and eye movements.

There is a phenomenon sometimes called perhaps erroneously the Mona Lisa effect in which a picture appears as if we are always directly in front of it. This is best understood by the eyes of the illustrated person looking directly out at us when we are in front of the picture and then seems to follow us around the room[11]. The Visual method would explain this because it always views an object (a picture) as if it were directly in front no matter its position.

The Visual method also permits the determination of balance in non-rectangular pictures or those seen at an angle. The calculation of a perfectly balanced non-rectangular picture is demonstrated using fig. 3. Previously I could only determine this empirically The lower half is identical to the balanced fig 4 and has a luminance of 124.8. The upper half of fig 4 has a luminance of 115.5. Were fig. 3 to be balanced then its upper half would have a luminance of 115.5. However, the light energy or luminance flux is spread out over the total area that includes the black rectangles so that the luminance of the total upper half will be less. The calculation is as follows: the luminance of 115.5 multiplied by the number of luminous pixels of just the luminous upper half

of the picture is equal to the luminance **L** of the total upper half multiplied by the pixel area of the upper half.

(189,360-54,000) x 115.5=189,360 x **L**, so that **L** = 82.6. 54,000 is the number of black pixels. Changing the upper right and left quadrants of figure 3 so that their pixels have an average luminance of 82.6 (including the black rectangles) creates a balanced picture. This is within the range of empirically determined values. Because pictures do not have their luminance equally distributed, after the black rectangles are placed on the upper quadrants, they have to be rebalanced using the average luminance.

Figure 3 the calculation of luminance in non-rectangular objects. The dimensions of the image is 526 x 720 pixels and each black rectangle is 150 x 180 pixels

bhh

Figure 4 – figure 3 without the obscuring black rectangles

In LED pictures there is a decoupling of two low level aesthetic effects. One relates to the ease of making eye movements which is not inhibited but varies in degree of imbalance while the other which rivets attention in an involuntary way when perfectly balanced and also in varying degrees as the picture becomes imbalanced. This is not contemplation. The attention riveting effect is, as so eloquently described by Delacroix, an artistic peak effect different but similar to the peak effects in other art forms which can be riveting in their own way and so may have a common pathway[36,37,38]. A "peak artistic experience" is characterized by the work commanding total involvement and concentration to the exclusion of everything else – a dissociative experience. The anatomical location for this might be discovered by viewing a balanced picture with reflected light both through a polarizing filter and a neutral density filter using fMRI imaging with subjects who both can or cannot see the effect. Based on work by Wu et al. and Duchemin et al, the effect on eye movements should be located in the the pretectal area of the midbrain which has been shown to be a major center of global motion processing[39,40]. The neurons influencing attention might be there also but distinguished by the on/off effect.

Addendum A

Eugene Delacroix:

> "There is a kind of emotion which is entirely particular to painting: nothing [in a work of literature] gives an idea of it. There is an impression which results from the arrangement of colours, of lights, of shadows, etc. This is what one might call the music of the picture...you find yourself at too great a distance from it to know what it represents; and you are often caught by this magic accord. In this lies the true superiority of painting over the other arts for this emotion addresses itself to the innermost part of the soul… [and] like a powerful magician, takes you on its wings and carries you away[11,17]."

Wassily Kandinsky describes the effect, but being unaware of de Piles' observations which would have permitted him to understand his sensations, drew the conclusion that it resulted from the absence of recognizable objects:

> "It was the hour of approaching dusk. As I was returning 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 full well, that the object [objective form] harms my paintings"[19].

Cézanne's comments about painting are most frequently recorded in conversations in which he repeatedly insisted that a painter must paint from nature[16]. However, his paintings are noted for their distortions especially the series of bathers in which both people and nature have been abstracted. Forms in nature as opposed to man-made forms have a fractal nature and do not have particularly salient properties[31]. I believe Cézanne was attempting to compose balanced pictures that enabled the gaze to move through them smoothly as it does when we looked at natural scenes. It would seem that he had no vocabulary to express this other than to say one must paint from nature.

The author would like to thank the Matlab Mathworks Help community for writing the code used in calculating the visual method of balance.

Supplemental Information is available for this paper with the pictures, calculations of balance, and statistical studies permitting complete reproducibility. There are additional pictures that can be used to test various hypotheses such as the statement above of ~1.07 +/- 03 as the degree to which the lower half has to be lighter to be balanced.

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