Pictorial balance is a bottom-up aesthetic property mediated by eye movements

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Abstract

Pictorial balance modulates the effects of salience and top-down direction on eye movements. When a perfectly balanced picture, a picture where balance has no effect on eye movements is viewed by someone who can disregard saliency and is innately disposed, the gaze is attentive to the entire picture without being directed to any one place and peripheral vision is facilitated. A study using balanced framed LED pictures showed that they are visually different to painters from identical pictures render unbalanced by a slightly different frame. The balanced pictures have bilateral quadrant luminance symmetry and a slightly more luminous lower half. A formula for the calculation of pictorial balance is presented. The more a picture is balanced, the more it will appear unified and harmonious. The name given by the author to this effect is pictorial coherency.

Introduction

A picture, a bounded flat image, corresponds to nothing found in nature or mental imagery. This includes the borderless images in European prehistoric caves (Schapiro 1969). It differs from an image without borders in that it evokes the percept of balance: the parts relate to both the center and the borders (Arnheim 1974 p. 10). Balance is both a bottom-up percept having primary aesthetic properties, and a top-down level concept, taught in schools. But balance of what and how? Color, form, tonal areas, and lines have been proposed. These somewhat immeasurable qualities have been said to be balanced around a geometric center or the principal pictorial axes defined by a center-of-gravity type of equation that is said to explain the perceptions of balance (Arnheim 1974, Poore 1903, Ross 1907). Any attempt to show that low level balance is determined by some sort of equation will be associated with this particular fallacious concept. However, in the same way that elements of salience such as color, contrast, and orientation are used to calculate the salient properties of a particular image, one might be able to calculate balance as a function of pictorial properties (Itti 1998).

Eye movements are predominantly influenced by saliency and top-down priorities. (Itti et al, Kowler, Krasovskaya 2019). These determinants of eye movements are large so that it is difficult to separate out the much smaller effect of balance. Locher and Nodine tried to do this by comparing eye movements in pictures that were thought to be balanced with variations of these pictures. Using trained and untrained observers, they found that the trained observers had more diverse exploration movements and fewer specific exploration movements in the more balanced compositions. (Nodine 1993), Locher P 1996, Locher et al 1996). These effects are certainly characteristic of balance but do not quantify the effects of imbalance.

Because there has been no way to create a picture with a specific degree of imbalance, to understand the general effect of balance one would have to create a perfectly balanced picture in which balance could have no effect on eye movements. In a perfectly balance picture if the viewer can disregard as much as possible top-down goal direction and bottom-up saliency, eye movements are unrestrained. Comparing eye movements in the perfectly balanced picture with an identical picture framed differently to make it unbalanced (and thereby avoiding the effect of a difference in saliency when one modifies a picture) should show the effect of balance. However, there is no obvious way to determine how the visual system determines pictorial balance. I thought that the solution to this problem was in the analysis of a very obscure effect observed by painters that creates a remarkable feeling of unity and harmony. There is no name or metaphorical description for the percept evoked by these pictures so it is discussed only when before such a picture in art schools, particularly ones devoted to abstract painting. This unexpected change in a painting from being remarkably unified and harmonious to something less so or the reverse is quite striking. Peripheral vision becomes more salient, creating the feeling of the whole picture being seen at one time without a need to focus on any pictorial element. I call this percept pictorial coherence.

Pictorial coherence was first noted by Roger de Piles, a French critic and painter around 1700. He described an assemblage of "lights and darks" in paintings creating an effect that was spontaneous and intense giving the impression that the viewer could gaze at the entire painting without focusing on any particular form (Puttfarken). Cézanne apparently noted this. Indeed, the inability to describe it gives his conversations a cryptic quality. Both Delacroix and Kandinsky give vivid descriptions (Doran p. 88-89, Delacroix p.67, Kandinsky p. 68).

Computer images that evoke it were created through experience acquired from many years of painting (Addendum A). Image analysis indicated that the percept resulted when an LED picture, centered at eye level and parallel to the plane of vision has equal luminance of the upper quadrants and the lower quadrants respectively with the upper half being slightly darker than the lower half by a factor of ~1.07 ± ~0.03 (where luminance is measured from 1 to 255 with black equal to 1 as measured by Photoshop CR2©).

While the aesthetic effect is very strong when seen in a picture by reflected light, the percept is diminished in LED pictures. The effect on eye movements is retained as will be discussed later. Because it is more subtle, a study of subject preference could not be done. Under these conditions the effect is not stronger than competing effects of color and contrast. Bertamini et al noted that observers preferred a printed reproduction to seeing the same picture in a mirror or on a monitor. In addition, it was noted that they preferred the mirror view of the actual image to the simultaneously transmitted LED image. Locher P 2001 made a similar observation. I believe that LED images increase saliency and decrease the effect of a surface which interferes with the percept. LED's had to be used to permit precise luminance determinations and reproducibility (all images are in the supplementary files). Since a white frame and a picture against a black

ground are treated as one visual object with respect to evoking coherence, there can be a comparison of a picture with and without the effect by simply changing its frame. This avoids the confounding variable of salience. If the observer is told to compare the two images and to disregard the frame, any perceived difference would be ascribed to the effect. A study was done to show that this percept is observable by some people, mostly painters according to the parameters established by the author. A painting exhibiting coherence is perfectly balanced; everything else will be called unbalanced. Most people, who observed the two identical pictures in succession, saw no difference. Only a group of painters and people who were very interested in looking at pictures were found likely to see it.

Materials and Methods

Each study consisted of ten pairs of images: Five in which one of the images was coherent and the other unbalanced (balanced or coherent pairs) and five in which both were unbalanced (unbalanced pairs). The 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 1a with either 1b or 1c. Study 2 compared figure 1b with 1c (only the white borders are seen when an picture is seen against a black ground.). Observers see sequentially a picture with one frame followed by the other on a calibrated iPad using the ColorTrue™ app and a Colorite device. The iPad image was verified to have the stated luminance balance through measurement of screen shots. The images on the iPad are approximately 5x6.75 inches and subtend visual angles of 19º and 23º respectively. The observers viewed the iPad parallel to the plane of vision at arm's length and were asked whether the two central images appeared to be the same or different. The pictures used for the studies are in Fig. 2. Images 1,3,5,7, 8 were the balanced pairs.

Fig. 1 The three possible image and border combinations

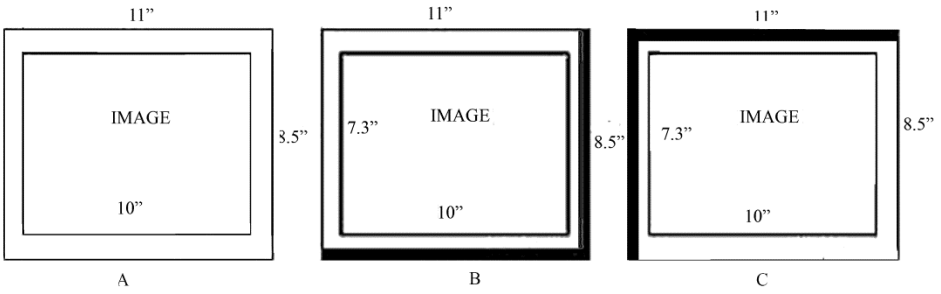

Fig. 2 Pictures used in the study pairs (see supplemental files)

The observers were predominantly artists of any age who gave their consent orally to participate in an anonymous study of how people look at pictures. No identifying information or medical history was obtained; there was no attempt to eliminate observers who were color deficient, have cataracts or have impaired binocular vision. The research study was done in accordance with the Helsinki Declaration (WHO). There were no requirements other than a willingness to follow the directions to carefully view the pictures and to answer questions as to whether picture pairs appeared different or the same. 45 observers were included in the first study and 39 observers in the second study. Observers were excluded if they rapidly said they could see no difference without careful examination or if they insisted 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 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.

Observers were shown pair of pictures on the iPad in sequence with the examiner seated slightly behind them. They were permitted, indeed encouraged to hold the iPad themselves as long as it was held correctly. They were told that it was thought that some pairs would be seen as the same and others different. There were no restrictions on the length of observation, and observers could return to a previous image as much as they wanted to. However, subjects were told that the difference if any was more in the way of a feeling than a distinct difference and were discouraged from making point by point comparisons. The difference was described as analogous to the difference between of monophonic vs. stereophonic music in that it is the same music but seems different.

Results and discussion

Four observers could identify all the balanced pairs correct, and 5 observers made one mistake. (Table 1) Although it could not be statistically proven, it is very suggestive that the effect is being seen. Some subjects thought they saw differences in color, one thought the depth of field was greater, and many saw differences but could not describe them.

Table 1 The Number of observers for each number of correct responses (see supplemental files for all results)

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

Among observers who perceived differences in any pair, many saw differences in both balanced and unbalanced picture pairs. Initially this was thought to be due to guessing. However, there is a strong correlation between the percent of pairs observed to be seen as different and the pair average distance (average imbalance). To understand this, I propose a formula which defines the observed state of perfect balance and explains observations implying a center-of-mass-like

effect. If a coherent picture with bilateral quadrant symmetry and a darker upper half can be said to be perfectly balanced i.e. some property is mathematically centered, and its center of luminance is located at the geometric center of the picture, then the standard formula for the center of mass of four connected objects can be used. In this formula average quadrant luminance L replaces the mass of each object:

$$X = (X_{ULQ}L_{ULQ} + X_{URQ}L_{URQ} + X_{LLQ}L_{LLQ} + X_{LRQ}L_{LRQ})/L_{TOTAL}$$
$$Y = (1.07)Y_{ULQ}L_{ULQ} + (1.07)Y_{URQ}L_{URQ} + Y_{LLQ}L_{LLQ} + Y_{LRQ}L_{LRQ})/L_{TOTAL}$$
$$L_{TOTAL} = (L_{ULQ} + L_{URQ} + L_{LLQ} + L_{LRQ})/4,$$

Balance = $\sqrt{X^2 + Y^2}$ which can also be represented as a vector $\vec{L} = X, Y$

Luminance L is measured on a scale from 1 to 255 with 1 being black. The y values of the upper quadrants are modified by 1.07 to account for the increased visual weight of the upper half. X_{ABQ} and Y_{ABQ} are the coordinates of the center of their respective quadrants, and L_{ABQ} is a quadrant's average luminance.

It was noted that the pairs were divided into two groups: one in which the average state of imbalance within the pair was low (the balanced pairs), and the other where the average imbalance was large. The balanced pairs were identified correctly by 40% of observers, and the unbalanced pairs were identified correctly by 75% of the observers. The correlation between average pair distance and correct identification was: $r(18) = 0.57$, $p = 0.013$ (Table 2). This indicates that observers distinguished the coherent pictures in the balanced pairs from unbalanced pairs.

It is to be noted that if the responses of "different" for both coherent and unbalanced pairs are compared with the inter-pair distances, the correlation is $r = 0.959$. There is no clear reason why the eye should relate same-difference to inter-pair distance.

Table 2 Pair average distance and percent of observers that correctly identified the pairs (according to the author) or identified the percent of pairs seen as different

	image pair	average pair distance	% correct	image pair	average pair distance	% correct	% same
1st Study	1	0.462	0.489	2	0.723	0.644	0.356
	3	0.318	0.356	4	1.894	0.711	0.289
	5	0.427	0.444	6	1.679	0.667	0.333
	7	0.509	0.378	9	0.944	0.822	0.178
	8	0.522	0.444	10	2.197	0.889	0.111
2nd Study	1	0.608	0.410	2	0.942	0.718	0.282
	3	0.652	0.359	4	2.153	0.846	0.154
	5	0.473	0.436	6	1.934	0.615	0.385
	7	0.658	0.282	9	1.389	0.744	0.256
	8	1.026	0.436	10	2.455	0.872	0.128

Mean	0.565	0.403	1.631	0.753
StDev	0.193	0.060	0.602	0.098

The use of an iPad in different lighting environments was necessary to bring the study to the observers as no laboratory was available. This increased the number of false negatives, i.e. coherent pictures being seen as unbalanced. The possibility of examiner influence cannot be excluded although an attempt was made to diminish this by not being in the sight of the subjects as they looked at the images. However, the results of the unbalanced pairs were contrary what I had expected which was that no one would see the unbalanced pairs as different. After all they are identical pictures.

Pictorial balance is extremely sensitive to small differences of quadrant luminance which explains its fugacity without precise viewing conditions (table 4). Changing the lighting spectrum or height at which the painting is hung destroys the effect. 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 arrived at through chance and even then is usually fleeting, and that there is no name for it; one can understand why it is not common knowledge.

Table 4 shows the right/left and top/down ratios for the 2nd study. The unbalanced pairs are in bold.

pair	lateral balance	top/down	pair	lateral balance	top/down
1	1.05	0.97	**6**	**1.04**	**1.37**
	1.00	1.06		**0.97**	**1.23**
2	**1.03**	**0.95**	7	0.94	0.97
	0.99	**1.01**		1.00	1.07
3	1.00	1.06	8	1.00	1.08
	0.93	1.16		1.10	1.26
4	**0.98**	**0.90**	**9**	**1.05**	**0.87**
	1.06	**0.83**		**0.98**	**1.01**
5	0.95	1.00	**10**	**0.80**	**0.96**
	1.00	1.07		**0.86**	**1.06**

With respect to eye movements I find that it is possible for the eye to glide smoothly through a coherent painting instead of jumping from place to place. The jumps themselves seem to be easier than with an unbalanced version of the same picture. It is simply less tiring to look at a

more balanced picture, or conversely it is much more tiring to look at a very unbalanced picture. Painters often learn to follow their eye as it moves through a picture to see whether it moves freely or is impeded as a means of evaluating balance and to remove "visual obstructions." During the study an observer who was clearly familiar with the effect in his painting but who did not identify the balanced pairs particularly well, was taught to slide his eyes around. He then identified every pair correctly. It was not that he perceived the effect but was sensitive to how it affected eye movements.

Conclusions

A picture is a controlled viewing experience; contrast, line, forms and color, etc are easily controlled so that saliency is diminished is minimized. When an innately capable observer views a picture with the ability to ignore saliency, then balance remains to directing the eye. With perfect balance there is no controlling effect on eye movement. One gazes at the whole picture and moves smoothly through it. To the reader whose eye always goes from one form to another, this might seem just as unusual as learning about the percept of coherence which Roger de Piles describes as seeing the whole picture at one time – "le tout ensemble" (Puttfarken).

Painters view pictures differently than untrained individuals (Nodine et al, Long et al, Zangemeister et al.). Antes et al (1991,1996) used fixation patterns to distinguish painters from non-painters, and Koide et al used a prediction model of a saliency map to show that artists are less guided by local saliency than non-artists Molnar (1981) thought that the quality of a composition was related to the ease at which the eye could see all areas of the picture, but did not take balance into account in doing this. Coherence facilitates this in an extraordinary way. The more balanced the picture, the easier it is for all areas to be easily seen, and so the more unified and harmonious, the picture will seem.
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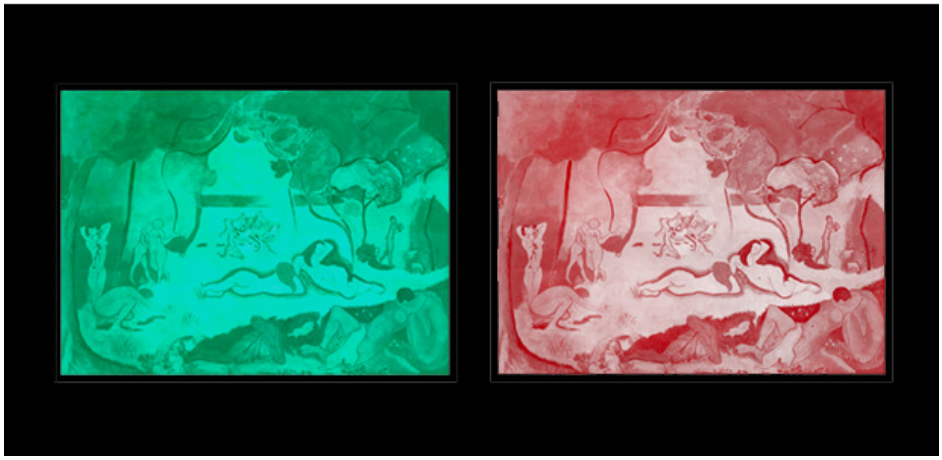
The importance of peripheral vision in the percept of coherence where the magnocellular cells predominate is shown through its suppression in an environment of red light. It is not seen in a balanced monochromatic red image but is seen in a balanced monochromatic green image of the same picture (fig. 3) (Livingstone et al, Awasthi et al, Chapman et al). It might be of interest that binocular vision is necessary to view the percept.

Fig. 3 balanced monochromatic red and green pictures

fig. 3



There are certain types of saliency that cannot be eliminated i.e. pronounced geometric or hard-edged and precisely defined forms, and many different forms that cannot be combined conceptually into fewer forms. The eye can learn to ignore the few major forms but cannot ignore multiple equally salient forms. While pictures with these salient characteristics may meet the luminance balance criteria, they will probably not be seen or are much less likely to be seen as coherent. A solid colored image modified to meet the criteria for coherence cannot be seen as coherent because, there is nothing for the eye to "see." There has to be something "there" to pay attention to.

Pictures as such are not part of the evolutionary development of humans, and they differ from images without borders because they evoke the percept of balance. Borders (as defined by the eye) change an image into a picture that is viewed as object. Objects stimulate the visual field far more than an image – a mere variation in color of sorts in an object. One intriguing idea is that they are the residue of a primitive visual system for evaluating object movement.

This work was done so that it could be easily replicated either with the original pictures in the supplementary data or with other pictures. I would recommend using rear projection of images. Gray-scale pictures on paper are possible but much more difficult because of the printer interface and the calibration of quadrant luminance. A study of eye movements with coherent and identical but unbalanced pictures could be done with three categories of subjects: those who could see the percept, those who cannot but enjoy looking at paintings and those who have no interest in paintings as such. It should be noted that with respect to proving the existence of coherence, this is not a cause and effect study. The ability of one observer who can identify 20 or more pairs correctly would show beyond a reasonable doubt that the effect exists.

In summary, balance is a bottom-up conveyer of aesthetic feelings through its effect on eye movements. It is determined by the luminance ratios of the pictorial quadrants using a specific

formula adjusted for the upper quadrants to be ~1.07±.03 times lighter. A perfectly balanced picture where there are no particularly salient features has a special effect, noted historically and by painters today; peripheral vision becomes salient causing the picture to appear unified and harmonious and the eye capable of gliding over the picture without fixating for long on any form. Pronounced geometric forms or many small forms prevent experiencing the percept. Since aesthetics is usually relative to fashion (and is both a positive and negative experience) the more a picture is balanced as seen by reflected light, the more it might seem pleasing.

Addendum A

The initial creation of balanced pictures for this study used a technique in which the eye seems to go to the quadrant that is "heaviest." In the process of creating a balanced picture as determined by Matlab©, quadrant luminance balancing was used as a first approximation because this is relatively simple in Photoshop©. I found that pictures with a center of luminance gravity at the geometric center are almost impossible to create. Quadrant image luminance characteristics can be changed in an unobtrusive manner and precise manner in Photoshop© through the use of the level command on an irregular shaped form and changing luminance by no more than ±0.05 at any one place.

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