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Spatial balance of color triads in the abstract art of Piet Mondrian

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Abstract. We examined the interactive contribution of the color and size of the three areas occupied by the primary colors red, yellow, and blue in adaptations of abstract compositions by Mondrian to the perceived weight of the areas and the location of the balance centers of the compositions. Thirty-six art stimuli were created by experimentally changing the colors in the three areas of six original works so that the resulting five variations and the original constituted the six possible spatial arrangements of the three colors in the three locations. In experiment 1, design-trained and untrained participants determined the location of the balance center of each composition seen on a computer screen and rated the apparent weight or heaviness of each color area. In experiment 2, untrained participants determined the location of the balance centers of the compositions when projected to their actual size. It was found that, for both trained and untrained participants, the perceived weight of a color, especially red and yellow, varied as a function of the size of the area it occupied. Furthermore, participants in both experiments perceived shifts in the locations of the balance centers between the originals and their altered versions. Only the trained participants, however, perceived significant shifts in balance centers among the five variations of the compositions, demonstrating their superior sensitivity to the contribution of color to balance structure. Taken together, the findings demonstrate the existence of a color – area – weight relationship among color triads in abstract displays and the influence of this relationship on color balance in abstract compositions.

1 Introduction

Many artists and art theoreticians assert that balance is the primary design principle by which the elements of a painting are organized into a cohesive perceptual and narrative whole that creates the essential integrity or meaning of the work. A balanced composition results when the structural elements and their qualities are poised or 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 painting are pitted against each other about a balancing point or center so that they appear anchored or stable. Such a composition may be said to be visually right (ie good) with respect to its structural organization (see Locher et al 1999b).

One feature of a composition that is a major contributing factor to its balance structure is the distribution of 'weight' in the composition (especially about the vertical and horizontal axes). The perceived weight of a pictorial element within the structural organization of a composition is determined by its size, shape, location within a composition, and its implied 'directionality'. Additionally, 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 (eg Albers 1963). One general principle concerning the use of color found in treatises on composition is that a large area of a dull, unsaturated color can be balanced by a small area of a highly saturated 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 (saturations). A long history of experimental investigations that required subjects to adjust the relative areas of two Munsell chips until the combination appeared 'balanced' has consistently shown that Munsell's formula for predicting color balance between pairs of colors works quite well (eg Alexander and Shansky 1976; Linnett et al 1991; Morris and Dunlap 1987, 1988a, 1988b). These studies have also shown that whether the two hues were complementary or adjacent on the color circle has little effect on the balance settings.

Typically, everyday color displays, such as paintings, pictures, and computer images, contain more than two colors. In such displays the weight of each color component is a function of the relationship between all of the compositional colors and the areas they occupy. Books and manuals on composition present a variety of techniques by which an artist can organize a pictorial field to achieve balance (eg Bearden and Holty 1969; Bouleau 1980). In addition, techniques for achieving symmetry and balance in commercially important images, such as computer interfaces, have appeared in the literature, along with empirical evidence demonstrating the pragmatic and aesthetic value of balance in such displays (eg see Ngo and Byrne 2001; Ngo et al 2000). One computer application of particular relevance to the present discussion is the Color Harmonizer developed by Moretti et al (2000). They embedded Munsell's formulaic approach to color harmony in this software tool that enables computer applications developers, who do not usually have the sense of color balance of an experienced artist, to color interfaces harmoniously. It enables one to automatically create balanced color schemes for computer interfaces which consist of many more than two colors and a large number of screen objects. According to Moretti et al, the Color Harmonizer takes into account data about the interface components, such as the types of screen objects used in the application, the characteristics of each object type (eg the total area it occupies—its 'importance'), and the interaction of each pair of object types, when constructing a harmonious color scheme. Moretti et al provide no empirical evidence, however, that the color strength of multiple display components created with the Color Harmonizer correlates with the perceived weight of these components.

To our knowledge, the interactive contribution of three color areas to their perceived weights and to the balance structure of a visual display of which they are a part has not been investigated empirically. This was the general purpose of the present research. Specifically, we constructed stimuli using six abstract paintings, listed below, by the artist Piet Mondrian. These compositions all contain variations of three different-sized rectangular areas, each of which is either red, blue, or yellow, within a lattice of vertical and horizontal black lines painted on an off-white background. We created five 'color variations' of each original by changing the colors in the three areas so that we had six compositions—the five variations and the original—which constituted all possible spatial arrangements of the three colors in the three locations. It should be noted that this research was not designed to test the visual correctness of Mondrian's paintings, and did not, therefore, attempt to reproduce the colors in his compositions exactly. In fact, for the purposes of the present experiment, the area and background colors were the same for all variations so that their chroma and value (see section 2.1 for details) were constant across the stimulus set. Thus, only the hue – area – weight relationship was investigated in this research.

Abstract works by Mondrian were chosen as the stimuli for several reasons. First, we wanted to keep to a minimum the role played by the 'forms' in which the colors are embedded. In a picture, as in daily life, colors are bound up with forms, objects, meanings, and memories, any or all of which may determine the perceived weight of a color as well as the pleasure or displeasure one feels when seeing a color. With respect to the compositions used as stimuli in this study, Arnheim (1988) notes that Mondrian "limits himself to the three fundamental primaries, whose renunciatory purity conveys a minimum of expression, a minimum of association with the things of reality" (page 104). Thus, associative effects of the color planes of the stimuli used in the present research have been controlled, or at least minimized. A second reason for using Mondrian's paintings as stimuli is that he has addressed the compositional problem of color balance 'experimentally' in the series of paintings he produced in the 1920s and 1930s. That Mondrian himself considered the paintings he completed during this period to reflect an optimization of the balance problem is suggested, according to McManus et al (1993), "by the lengthy period during which the pictures were kept in his studio, to be worked on, studied and revised, and by the existence of a small number of unfinished pictures in which it is clear that lines are being moved by small distances by the use of over-painting" (page 85).

Furthermore, McManus et al (1993) have provided empirical support for the visual rightness of some original Mondrian paintings of this period. They asked art students and students untrained in the arts to make a preference judgment between computer facsimiles of twenty-five original Mondrian paintings and two modified versions of each picture. The proportional relations of the black compositional lines of the two perturbations were experimentally modified by a relatively small amount. McManus et al found that, in general, participants preferred the original Mondrians to a greater extent than predicted by chance; participants untrained in art were slightly more accurate than the art students in discriminating real from pseudo-Mondrians. However, as one might expect, it was observed that some subjects in both groups were better at the task than others, and that the task was easier for some pictures than others. McManus et al suggest that their findings provide evidence that Mondrian had achieved some universal principle of compositional order in the originals. Additional evidence of the visual rightness of Mondrian's compositions is reported by Latto et al (2000). They found that college students untrained in the visual arts showed a preference for Mondrian compositions seen in the orientation of the originals rather than for the pictures presented in one of eight different oblique orientations.

In the present paper, to investigate the color – area – weight relationship for color triads, participants in experiments 1a and 1b viewed the set of thirty-six pictures (the six original compositions and the five altered versions of each composition) in different random orders. Their task was to determine the perceived balance center of each composition, seen one at a time, and to assign a weight to each of the color areas contributing to the location of the balance center. Thus, as previously mentioned, the purpose of the first experiment was to study the perceived heaviness of the primary colors red, blue, and yellow as a function of the size of a colored area within an abstract display and the influence of these factors on the location of the perceived balance center of the composition.

Training in visual arts is another factor that might be expected to influence color balance perception. Evaluative judgments of structural and aesthetic qualities of pictures, such as their complexity, interestingness, and pleasantness, have often been shown to differ reliably as a function of expertise in the visual arts (eg see Csikszentmihalyi and Robinson 1990). However, Locher et al (1996) observed that 'sensitivity' to pictorial balance does not require training in the visual arts and may, as Arnheim (1988) and others assert, be established intuitively by the eye. The art stimuli used in Locher et al's research consisted of color reproductions of representational and abstract paintings and an experimentally reconstructed less-balanced version of each. Participants in their study determined the location of the perceived balance center of each composition and then assigned weights to the pictorial features that contributed to the location of the balance center. It was found that design and museum professionals were in agreement with individuals untrained in the visual arts as to the apparent weights of the structural components underlying the balance organization of a painting, as well as the location of the balance centers. For all participants, disruption of the balanced organization of the original compositions led to reliable shifts in these pictorial characteristics between the originals and their less-balanced perturbations.

As previously mentioned, McManus et al (1993) also found little overall difference in the preference for original versus pseudo-Mondrians between art students and untrained individuals, and Latto et al's (2000) untrained participants preferred Mondrians seen in their actual orientation to those displayed obliquely. Taken together, these findings support the view that sensitivity to color balance does not require training in the visual arts. To test this assertion, we observed in experiment 1b whether locations of the perceived balance centers of the set of stimuli were similar for individuals trained in design theory and those with no such training.

Another factor that might influence color balance perception is the size of the image seen. Wurmfeld (2000) notes that many abstract painters, including Mondrian, effect both a spatial and a temporal organization in their compositions. As a viewer scans the structure of a large abstract picture, the perceived organization of the image may change and the weight of its component elements—the colored areas and black lines in the present set of stimuli—may take on different weights than when the same display is viewed in a more holistic fashion on a monitor. It is possible that temporal or successive contrast effects of the colors on each other may vary under the two viewing conditions (see Linnett et al 1991). For example, in the larger image, the afterimage of the color occupying the smaller area might have less influence on the appearance of the color occupying the large area. In a second experiment, the six versions of each painting were shown to participants as projected images that were the actual size of the original painting. The perceived location of the balance center of each composition was indicated by participants untrained in the visual arts. By comparing the locations of the balance centers in the compositions seen at actual size with their locations in the images viewed on a computer screen seen in experiments 1a and 1b, we were able to assess whether the induced structural framework that helps determine the role of each element within the balance system of the compositions differs as a function of the size of the visual display. Results based on actual-size images also have the potential to add to the ecological validity of findings obtained from computer-screen images.

In sum, the purpose of the experiments was to examine factors that contribute to the perceived balance of color triads in abstract art. Specifically, we investigated the interactive contribution of the color and size of the areas occupied by three primary colors to the perceived weight of the areas and the location of the balance centers of the compositions. Additionally, we studied the influence of viewer expertise in design theory and the size of the image seen on the dependent variables.

2 Experiments 1a and 1b

2.1 *Method*

2.1.1 *Participants.* Fifteen male and fifteen female undergraduate college students from Montclair State University volunteered for experiment 1a. They ranged in age from 19 to 27 years, with a mean age of 22.8 years. Only individuals who reported no formal education or studio training in the visual arts were accepted as subjects. Participants reported no known problems with their color perception.

The thirty volunteers for experiment 1b were undergraduate students at Delft University of Technology. They ranged in age from 19 to 25 years. Fifteen participants (five females and ten males) had no formal education or studio training in the visual arts.

The group of fifteen design-trained individuals (seven females and eight males) were all students on the Industrial Design Engineering Program at the university. The focus of their lectures, form exercises, and design projects was the role of design knowledge in relation to the creativity of design solutions.

2.1.2 *Stimuli and apparatus.* The stimuli for these studies were adaptations of six paintings by Mondrian. The original works and the measurements for each original presented in this study (referred to as compositions 1–6) were: composition 1—*Composition with Red, Black, Blue, Yellow and Gray* (1928; 50 cm $\times$ 48 cm); composition 2—*Composition with Red, Blue, Yellow and Black* (1929; 45.5 cm $\times$ 45 cm); composition 3—*Composition with Red, Blue, Yellow and Black—Composition Number III* (1929; 50.5 cm $\times$ 50 cm); composition 4—*Foxtrot B* (1929; 50 cm $\times$ 50 cm); composition 5—*Composition with Red, Yellow and Blue* (1930; 51 cm $\times$ 51 cm); and composition 6—*Composition with Red, Yellow and Blue* (1935; 56 cm $\times$ 55 cm). Renditions of the six originals are shown in figure 1. As seen in the figure, each original consists of vertical and horizontal black lines extending either to the edge of the pictorial field or to another black line, and three solid color areas on a white background. The three color areas differ in size and each is a different primary color—either red, blue, or yellow—as indicated in figure 1. The six paintings used to create the stimuli were selected because the originals are comparable in actual size, and because the sizes of the three colored areas in each composition varied across the stimulus set.

We created five color variations of each original by changing around the colors in the three areas so that the five variations and the original composition constituted the six possible spatial arrangements of the three colors in the three locations. Thus, the stimulus set consisted of thirty-six pictures, that is the six versions of each of the six compositions.

The stimuli were displayed on a high-resolution 17 in color monitor (75 Hz) and the experiment was controlled with a Macintosh PowerPC 8600. The screen images of the pictures were square and 7 in (17.8 cm) on a side. They were presented one at a time in the middle of the screen against a gray background. The R, G, B (0–256) numbers for the color guns on the monitor for each of the display colors were: red (220, 0, 0); blue (0, 0, 152); yellow (255, 223, 0); black (1, 1, 1); white (231, 231, 231); and the gray background (144, 144, 144).

Participants were tested individually in a small laboratory illuminated by diffuse overhead light. They sat approximately 40 cm from the screen. At this distance the pictures subtended a visual angle of approximately 25 deg both vertically and horizontally. A green open circle of diameter 1 cm appeared on the screen over the picture. When the viewer had decided upon the location of the balance center, he/she moved the circle to that location with the mouse and then clicked an OK button on the screen to the right of the picture that recorded the $x-y$ coordinates of the balance center. While subjects were deciding on the location of the balance center and rating the weight of each color area, they were able to extinguish the green circle by moving the cursor off the display. In so doing, the circle was not visible as participants made their decisions concerning the location of the balance center and the perceptual weights of the color areas.

2.1.3 *Procedure.* The procedure was the same for experiments 1a and 1b. Each participant viewed, in a different random order, the set of thirty-six stimuli one at a time on the computer screen. Following unlimited examination of each picture, he/she decided upon the location of the balance center and then stated the ‘weight’ of each of its three color areas using the 10 point scale described below. The experimenter recorded these ratings. The participant then used the cursor to indicate on the display the perceived

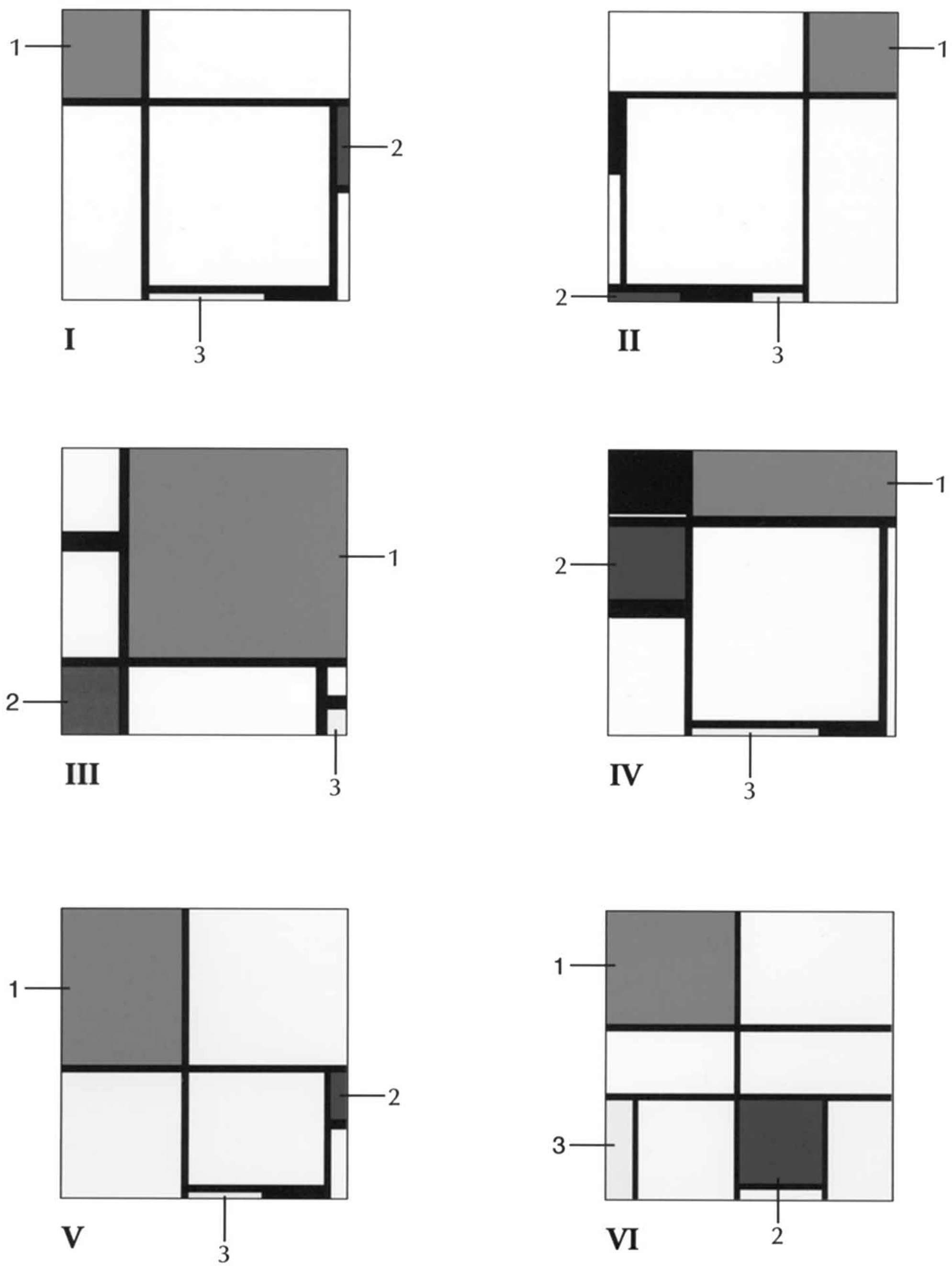


Figure 1. Renditions of the six original compositions by Mondrian used as stimuli. Titles of the works are: I = *Composition with Red*, *Black*, *Blue*, *Yellow and Gray* (composition 1); II = *Composition with Red*, *Blue*, *Yellow and Black* (composition 2); III = *Composition with Red*, *Blue*, *Yellow and Black—Composition Number III* (composition 3); IV = *Foxtrot B* (composition 4); V = *Composition with Red*, *Yellow and Blue* (composition 5); and VI = *Composition with Red*, *Yellow and Blue* (composition 6). Areas labeled 1, 2, and 3 are red, blue, and yellow, respectively, in the original compositions. These figures are available in color. A color version of this figure can be viewed on the *Perception* website at http://www.perceptionweb.com/misc/p5033/.

position of the balance center. When the participant was satisfied with his/her response, he/she clicked the OK button and the next picture was presented.

The following instructions were read by the participant:

> "In this experiment you will be shown a set of pictures composed of black lines and three colored areas on a white background. These pictures are reproductions of abstract paintings by the artist Piet Mondrian. Your task will be to examine each picture carefully and make several decisions concerning the structural organization created by the red, yellow, and blue areas within it.
>
> Every component of a picture has a kind of perceptual weight or perceptual force on the eye that is dependent upon such factors as a component's color, its size, its location in the picture, and its relationship to the other parts of the composition. Together, the perceptual forces of a picture's parts create its organization. Somewhere within the arrangement of the components of every picture there is a common center. This is the middle of the composition. It is the point at which the perceptual forces created by the picture's parts balance each other.
>
> In this experiment you will perform two tasks on each picture seen on the computer screen. First, you are to decide where the balance center of a picture is located. A picture's balance center need not be, and frequently is not, located at the actual center of the picture. Focus on the structural arrangement of the entire picture as you decide upon the location of its center. Try not to let your color preferences or how much you like the composition influence your judgment of a picture's center.
>
> After you have indicated the location of a picture's balance center you are to rate the visual weight of each colored area; that is, rate how much each colored area contributed to your decision concerning the location of the balance center of the picture. You are to use a rating scale from 1 to 10. Ten indicates that a given colored area had a very high degree of visual weight and influenced you very much in determining the center A colored area that had relatively little or no influence on your decision should be assigned a rating of 1. Assign a rating of 5 to those areas that influenced you moderately. [The rating scale described was taped below the computer screen.] Please use the full range of ratings as you complete the experiment. Once again I ask that you not let your color preferences or how much you like the composition influence your judgment of a colored area's weight."

If a participant had any questions concerning what was meant by the center of a picture or the perceptual weight of a colored area, these were answered. It was observed that participants with no formal training in the visual arts had little difficulty grasping the notion of perceptual weight and balance center. The computer procedure was then demonstrated to the participant.

2.1.4 *Data analyses.* The combined perceived weight data for experiments 1a and 1b were analyzed separately for each of the six compositions with a 3 (participant group) $\times$ 6 (version: the six versions of a given composition) $\times$ 3 (picture area: the three color areas of a composition) mixed unweighted means ANOVA factorial design. The three participant groups consisted of the untrained individuals in experiments 1a and 1b and the design-trained individuals in experiment 1b. For purposes of analysis, the three color areas of each picture were assigned the numbers 1, 2, and 3, as shown in figure 1. Participant group was a between-subjects factor and picture version and color areas were within-subjects factors. Simple main-effects analyses were conducted to interpret significant interaction effects.

Balance center data for experiments 1a and 1b were analyzed in combination with those data obtained from participants in experiment 2 and results are reported later in this paper.

2.2 *Results*

2.2.1 *Effect of color on the perceived weight of the three color areas in each picture.* Table 1 presents the average weights assigned by the three groups of participants to the three color areas in each version of the six compositions. Results obtained for the

Table 1. Average ratings of the perceived weight of the three areas in each version of the six compositions. The color of each area in each version is indicated by R for red, B for blue, and Y for yellow.

Area	Version i	ii	iii	iv	v	vi
Composition 1						
1	R 6.59[a]	R 6.39[b]	B 5.96	B 6.19	Y 5.52[ab]	Y 5.51[ab]
2	B 3.08	Y 3.19	R 3.06	Y 2.74	B 3.01	R 2.88
3	Y 2.92	B 2.73	Y 2.81	R 2.81	R 3.02	B 2.83
Composition 2						
1	R 6.06[a]	R 6.12[bc]	B 5.62	B 5.84	Y 5.38[ab]	Y 5.45[c]
2	B 2.55	Y 2.38	R 2.95	Y 2.83	B 2.91	R 2.70
3	Y 2.19	B 2.51	Y 2.39	R 2.59	R 2.57	B 2.62
Composition 3						
1	R 8.93	R 8.88	B 8.84	B 8.83	Y 8.31	Y 8.42
2	B 3.56	Y 3.29	R 3.63	Y 3.74	B 3.79	R 4.02
3	Y 1.86	B 1.94	Y 1.89	R 2.25	R 2.52	B 2.11
Composition 4						
1	R 7.47[ab]	R 7.45[cd]	B 7.18	B 7.07	Y 6.82[ac]	Y 6.51[bd]
2	B 4.95	Y 4.33	R 5.18	Y 4.71	B 5.03	R 5.17
3	Y 2.42	B 2.54	Y 2.63	R 2.86	R 3.14	B 2.51
Composition 5						
1	R 7.97[a]	R 7.94[b]	B 7.74	B 7.80[c]	Y 7.29	Y 7.08[abc]
2	B 3.06	Y 2.83	R 3.34	Y 3.00	B 2.99	R 3.27
3	Y 2.21	B 2.09	Y 2.35	R 2.47	R 2.68	B 2.20
Composition 6						
1	R 7.02	R 7.17	B 7.17	B 7.14	Y 6.62	Y 6.74
2	B 5.32	Y 5.27	R 5.43	Y 5.16	B 5.27	R 5.33
3	Y 3.35	B 3.82	Y 3.85	R 4.03	R 3.95	B 3.77

Note: Standard errors range from 0.16 to 0.27. Mean weight values in a row with the same superscript letter are significantly different at $p < 0.05$.

ANOVAs performed on the perceptual-weight data and the simple main effects analyses of significant interaction effects are shown in table 2.

As seen in table 2, the main effect for participant groups was not reliable for any composition, nor were interaction effects involving this factor significant, except in the case of composition 3, as described below. Thus, untrained participants in experiments 1a

Table 2. Analyses of variance results (F values) of perceived weights for each composition as a function of participant group, version, and size of colored area.

Source	df	Composition 1	2	3	4	5	6
Group (A)	2, 57	0.23	0.68	0.92	0.56	0.46	1.24
Version (B)	5, 285	1.87	0.65	1.64	1.42	1.60	1.23
Size of colored area (C)	2, 114	427.60**	517.32**	718.58**	411.05**	30.80**	281.03**
$A \times B$	10, 285	1.60	1.72	1.44	0.61	1.27	0.93
$A \times C$	4, 114	0.19	0.14	12.62*	0.29	0.25	0.22
$B \times C$	10, 570	2.92*	4.53*	4.75*	2.84*	2.79*	1.68
$A \times B \times C$	20, 570	0.87	0.44	2.20*	1.46	0.47	1.01

$*p < 0.01$, $**p < 0.001$.

and 1b and the design-trained individuals in experiment 1b were in substantial agreement as to the perceived weights of the different areas across versions and compositions. The mean ratings presented in table 1 are, therefore, not shown as a function of group membership.

The perceived perceptual weight of the three color areas in the six compositions varied significantly as a function of their size and color, as indicated by the highly significant main effect for size of colored area for all compositions (see table 2). As should be the case, the largest color area of each composition (labeled 1 in table 1 and in each picture in figure 1) was perceived by all participants to be much heavier, on average, than the two smaller color areas. Additionally, average ratings of perceived weight for the two smaller areas in each composition (areas 2 and 3) correspond to the actual size of the areas. That is, the two smaller areas in compositions 1, 2, and 5 cover approximately the same percentage of each pictorial field (viz 2.2% and 1.6%, 1.0% and 1.4%, and 1.0% and 1.0%, respectively) and their corresponding mean perceived weights do not significantly differ ($M = 2.85$ versus $M = 2.87$, $M = 2.72$ versus $M = 2.28$, and $M = 3.07$ versus $M = 2.33$, respectively). On the other hand, the fact that area 2 in compositions 3, 4, and 6 is larger than area 3 (viz 5.0% and 1%, 6.6% and 2.4%, and 8.0% to 4.0%, respectively) is reflected in the observed significantly higher values of perceived weight for area 2 versus area 3 ($M = 3.67$ versus $M = 2.09$, $M = 4.89$ versus $M = 2.68$, and $M = 5.29$ versus $M = 3.65$).

A significant area × version interaction was also found for five of the six compositions (see table 2). Follow-up analyses revealed that the weight of the larger area differed significantly as a function of its color for compositions 1, 2, 4, and 5 for all participants. As shown in table 1, when the large area of these stimuli was red in versions i and ii, it was perceived to be significantly heavier in weight than when that area was yellow in versions v or vi. When blue in versions iii and iv, the largest area's average weight fell between the weights assigned when the area was either red or yellow. Follow-up analyses revealed, however, that these differences were not reliable with but one exception, namely, in composition 5. In this case the large area was rated as heavier when blue in version iv than when yellow in version vi.

Results for compositions 3 and 6 differed from those for the other four works. Specifically, none of the six color arrangements of composition 6 resulted in reliable differences in the perceived weight of the three areas for any group of participants and, with respect to composition 3, only design-trained participants perceived differences in the weights of the areas between different versions. ANOVA results for composition 3 (see table 2) revealed a significant three-way interaction that subsumed significant group × version and version × area interactions. Follow-up analysis indicated that when the large area in composition 3 was either red (versions i and ii, $M = 8.26$ and $M = 8.46$, respectively) or blue (versions iii and iv, $M = 8.21$ and $M = 8.10$, respectively) it was evaluated by design-trained participants as significantly heavier than when yellow in version v ($M = 7.26$). Additionally, when area 2 was red in version vi ($M = 4.46$), the area was perceived to be significantly heavier than when blue or yellow in versions i or ii ($M = 2.93$ and $M = 2.81$, respectively). Follow-up analysis also revealed that design-trained participants evaluated area 2 as significantly lighter in version i than did untrained individuals ($M = 2.93$ versus $M = 3.87$, respectively). As mentioned, neither group of untrained subjects perceived the average weight for any of the three color areas in composition 3 to be significantly different across its six color variants. These findings indicate that the color – area – weight relationship in this composition was perceptually salient only to the sophisticated participants. As seen in figure 1, this composition has the greatest disparity between the size of the two smaller color areas and the largest color area, which occupies approximately 65% of the entire pictorial field.

2.3 *Discussion*

These findings provide empirical evidence for a color – area – weight relationship for the color triads in the visual displays studied. That is, the perceptual weight of a color, especially red and yellow, in the stimuli was found to vary as a function of the size of the area it occupied. The nature of this relationship can be summarized in the following general terms for the compositions used as stimuli in this study. When the size of the largest of the three color areas in a composition covers a relatively small percentage of the pictorial field, namely 9%, 9%, 16%, and 23% in compositions 1, 2, 4, and 5, respectively, significant differences in the perceived weight of the large area as a function of color were observed by both untrained and design-trained participants. When this area was red it was perceived to be heavier in weight than when the area was yellow.

The observed red – blue – yellow order of perceived weight of areas in these stimuli is in accord with findings reported by Pinkerton and Humphrey (1974). Their participants 'weighted' circular displays colored either red, orange, yellow, green, or blue against a white stimulus of constant brightness. Pinkerton and Humphrey found that yellow was rated significantly lighter than all other colors and red was rated significantly heavier than green, orange, and blue. McManus et al (1985) had participants locate the balance point for abstract stimuli consisting of one or two squares whose color (red, blue, or green), size, and position were varied within the display field. With respect to the influence of color on the perceived balance point of the displays, McManus et al's results indicated that the square was seen as significantly heaviest when it was red, and when it was blue it was seen as significantly heavier than when green. Additionally, the observed red – blue – yellow order of the perceived weight of areas in the present study is in accord with the voluminous literature on the personal and cultural meaningful qualities of colors (see Kreitler and Kreitler 1972; Recio 1995). With respect to the symbolic meaning of colors, red is consistently perceived as powerful, intense, strong, vigorous, energetic, and aggressive. Thus, it is not surprising that the large colored areas appeared heaviest when red.

The present findings also suggest that sensitivity to the oppositional relationship between compositional colors with respect to their color – area – weight relationship may, for certain compositional arrangements, require training in the visual arts. This assertion is based on the observation that when a color area occupies a much larger percentage of a pictorial field, as in composition 3, the expanse of color in the large area was seen by those untrained in design theory as exhibiting a comparably high degree of weight regardless of whether the area was red, blue, or yellow in color. Design-trained participants, on the other hand, perceived a difference in the weight of the largest area of composition 3 when it was red as contrasted with yellow. Additionally, they rated the weight of area 2 (see figure 1) of this composition as heavier when it was red than when it was either blue or yellow.

Evidence of a color – area – weight relationship for the color triads observed in the present study extends the findings of a similar relationship for color pairs reported by McManus et al (1985), and Pinkerton and Humphrey (1974). The question raised by all of these observations is why people, untrained or trained in the visual arts, should see any equivalence between color and weight? Pinkerton and Humphrey have pointed out that explanations based on associations between psychological properties of color and their apparent weight (eg red = intense) have no explanatory power because the reasons for the associations themselves are unclear. To date, no plausible explanation has been advanced to explain the mechanisms underlying the color – weight relationship, nor can we provide one.

3 Experiment 2

In this experiment participants untrained in the visual arts indicated the perceived balance centers of the six versions of each composition when shown as projected images that were the actual size of the original painting. The positions of these centers were then compared with the balance center data obtained for the images viewed on a computer screen in experiments 1a and 1b, to determine whether the size of the visual display influences the perceived balance structures of the compositions used as stimuli. Participants in this experiment did not rate the perceived weight of the three colored areas in each stimulus, as was done in experiments 1a and 1b.

3.1 *Method*

3.1.1 *Participants.* The participants were twenty-three volunteers ranging in age from 19 to 43 years. None of these individuals had any formal education or studio training in the visual arts

3.1.2 *Stimuli and apparatus.* The stimuli were projected onto a screen using an LCD projector. Participants stood 2 m from the screen. At this distance, the largest picture, *Composition with Red*, *Yellow and Blue* (51 cm $\times$ 51 cm), subtended 14.4 deg. The smallest of the six paintings, *Composition with Red*, *Blue*, *Yellow and Black* (45.5 cm $\times$ 45 cm), subtended 12.6 deg.

3.1.3 *Procedure.* The procedure used in experiments 1a and 1b to record the location of the balance center in each stimulus was used in experiment 2.

3.2 *Results*

Figure 2 contains plots of the perceived balance centers for all versions of each composition shown separately for the four groups of participants. In each plot, the black dots represent the balance centers assigned by participants to the original composition, the gray level of the tiles behind the dots depicts the frequency of balance centers within that part of the pictorial field assigned to the five manipulated versions of the composition. For each composition four plots are shown, one for each of the four groups of participants—the untrained participants in experiment 1a, the untrained participants in experiment 1b, design-trained participants in experiment 1b, and the untrained participants in experiment 2.

3.2.1 *Perceived balance centers for the original compositions.* Examination of the full set of plots in figure 2 reveals that participants were in strong agreement as to the location of the balance centers in the original compositions. This is indicated by the fact that there is relatively little scatter in the distribution of these data points. Furthermore, the way in which the pictorial organization of each original composition contributes to its balance structure can be seen in its respective plot. Note in figure 2 that most participants perceive the balance centers for compositions 1 and 5 to be located near the geometric center of each pictorial field. The balance centers of composition 4 are also clustered near its geometric centre; however, there was a clear tendency for design-trained participants to have placed the centers slightly to the left and above the center of the pictorial field. We speculate that this is due to the perceived weight of the large expanse of color concentrated in areas 1 and 2 of the composition's upper left quadrant, as seen in figure 1. In compositions 2 and 3, the balance centers appear to be aligned with the diagonal axis extending from area 1 in the upper right pictorial field to area 2 in the bottom left region. Finally, the organization of pictorial components in composition 6 results in the balance centers being perceived to fall along the horizontal axis, somewhat to the left of the geometric center.

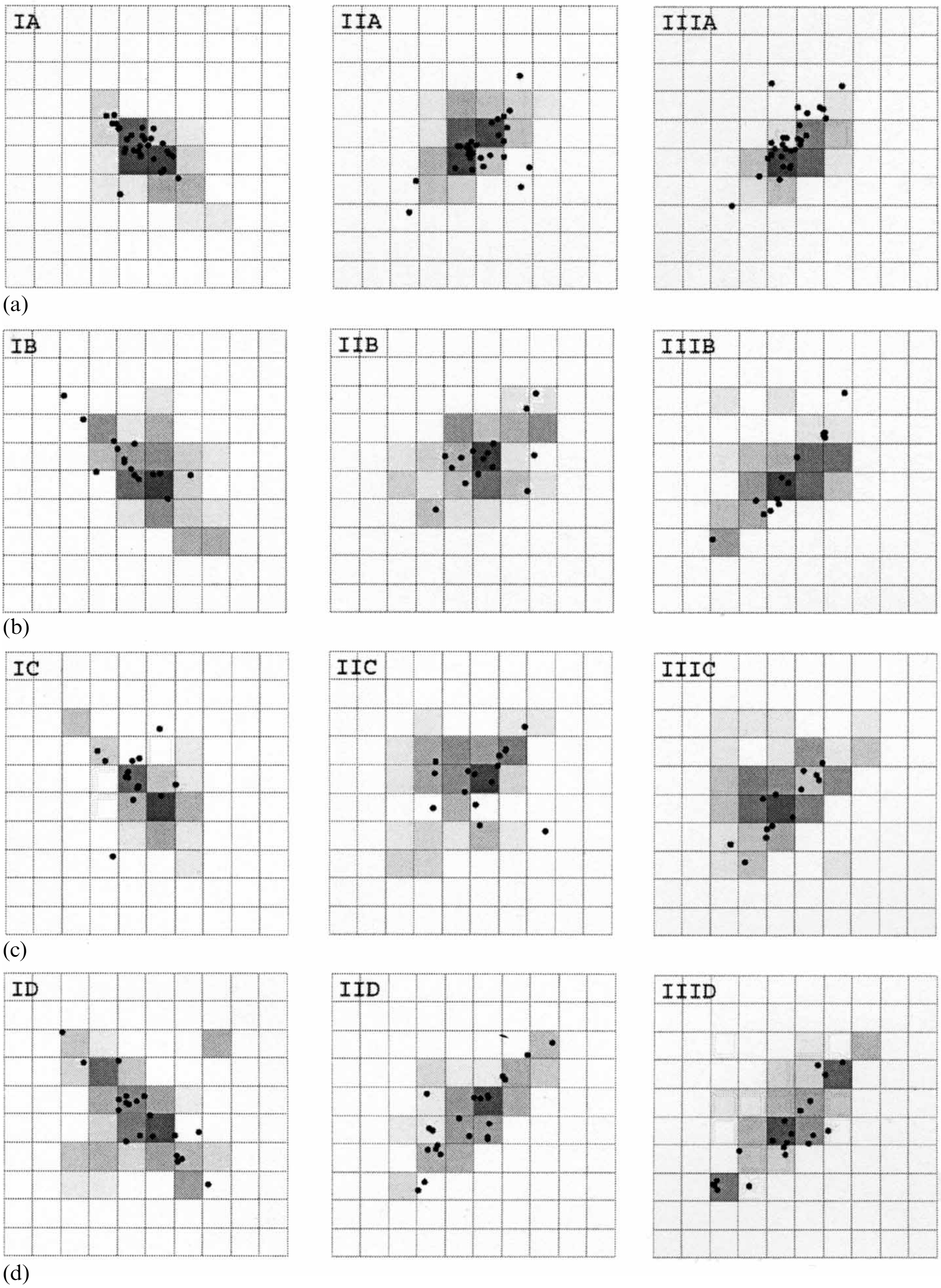
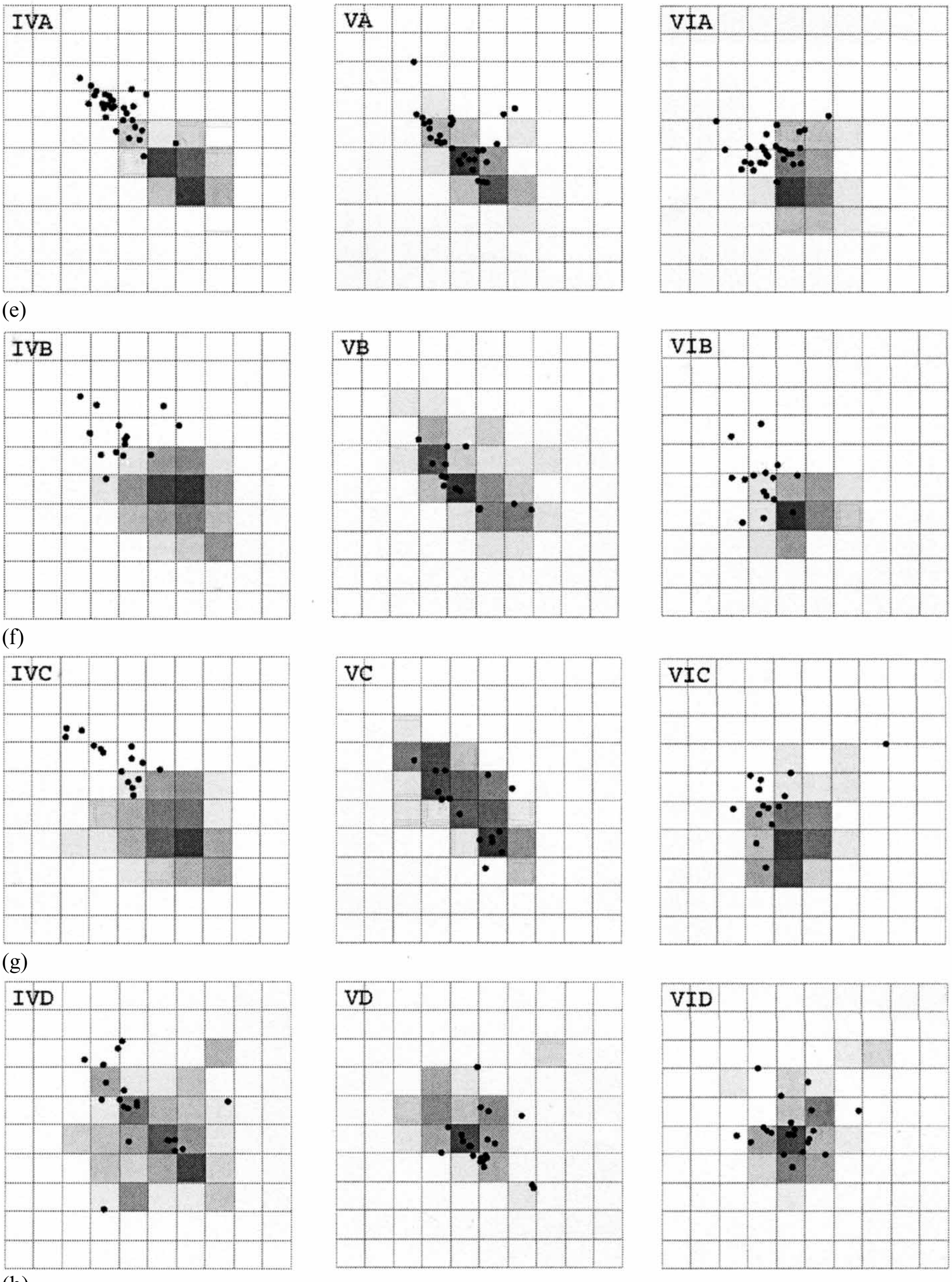


Figure 2. Plots of the perceived balance centers for all versions of each composition for the four groups of participants. The six compositions are: I = *Composition with Red, Black, Blue, Yellow and Gray* (composition 1); II = *Composition with Red, Blue, Yellow and Black* (composition 2); III = *Composition with Red, Blue, Yellow and Black—Composition Number III* (composition 3); IV = *Foxtrot B* (composition 4); V = *Composition with Red, Yellow and Blue* (composition 5); and VI = *Composition with Red, Yellow and Blue* (composition 6). Plots labeled A, B C, and D



(e)

(f)

(g)

(h)

Figure 2 (continued)
present data for the untrained participants in experiments 1a and 1b, design-trained participants in experiment 1b, and untrained participants in experiment 2, respectively. In each plot, the black dots represent the balance centers indicated by participants for the original composition, the gray level of the tiles behind the dots reflects the frequency of balance centers within that part of the painting for the five manipulated versions of the painting. Darker tiles reflect higher concentrations of assigned balance centers.

3.2.2 *Perceived balance centers for the altered versions.* It can be seen in figure 2 that there is greater scatter in the perceived balance centers for the altered versions than for the corresponding originals. This suggests that the structural organizations of the original compositions that were presumed to be balanced were disrupted to some degree by the different arrangements of colors in the altered versions. To determine whether the differences in scatter observed in figure 2 reflect statistically reliable shifts in assigned balance centers between each original and its altered versions, we computed the Euclidean distance between the balance center of each altered version and the balance center of its corresponding original for each participant. Distances were expressed as a percentage of the total display width, thereby making measures of distance for the small and large display fields used in experiments 1 and 2 comparable.

Table 3 presents the average differences in distance between the balance centers of the originals and their five perturbed versions for each participant group and each composition. Distance data were analyzed for each of the six compositions separately with a 4 (participant group) $\times$ 5 (altered version: the five altered versions of a given composition) mixed unweighted means ANOVA. The four participant groups consisted of the untrained participants in experiment 1a, the untrained participants in experiment 1b, the design-trained participants in experiment 1b, and the participants in experiment 2. Participant group was a between-subjects factor and altered version was a within-subjects factor. ANOVA results for the six compositions are presented in table 4; results of follow-up analyses are shown in table 3.

As seen in figure 2, there appears to be much greater deviation between the balance centers of the altered versions and their corresponding originals for the design-trained participants than for the two groups of untrained participants in experiments 1a and 1b. This suggests that trained participants were influenced by variations in the colored areas in the altered versions to a greater extent than were untrained participants. In fact, the average shift in the location of the perceived balance centers of the altered versions from the balance centers of the originals for the entire stimulus set is 17.3% of the display field for the trained participants, and 9.9% and 12.1% for the untrained participants in experiments 1a and 1b, respectively. Additionally, the scatter of balance centers for the altered versions appears relatively comparable in figure 2 for the trained participants and those who saw the compositions in their actual sizes in experiment 2. The average difference in distance between all originals and their altered versions was 16.2% for the participants in experiment 2.

Results of the ANOVAs performed on the distance data confirm these observations. As shown in table 4, the main effect of participant group was significant for each composition. Follow-up analyses reported in table 3 revealed that average shifts in assigned balance centers between originals and their altered versions did not differ reliably between the two groups of untrained participants in experiment 1 for any of the six compositions. On the other hand, balance centers of the altered versions were shifted to a significantly greater extent from those of the originals by the design-trained participants compared with those of the untrained participants. As seen in table 3, this was the case for all compositions in experiment 1a, and for compositions 2 and 3 in experiment 1b. Additionally, follow-up analyses showed that the average shift in balance centers between all originals and their altered versions did not differ reliably between trained participants and those who saw the pictures in actual size. There was, however, a significantly greater shift in balance centers between untrained individuals in experiments 1a and 1b, and those in experiment 2 for compositions 2, 3, 4, and 5.

Analyses of variance revealed that the main effect for version was not reliable for any of the six compositions. However, the group $\times$ version interaction was significant for compositions 1, 3, 4, and 5 (see table 4). Simple main-effects analyses performed to examine the nature of these interactions showed that in each case shifts in the locations

Table 3. Average distances (percentage of picture display field) between the balance centers of original compositions and their five altered versions for the four groups of participants. Participant groups: I, untrained participants in experiment 1a; II, untrained participants in experiment 1b; III, design-trained participants in experiment 1b; IV, untrained participants in experiment 2.

Group	Altered versions		Row mean			
	i	ii	iii	iv	v	
Composition 1						
I	11.8	11.7	11.1	11.5	10.4	11.3^{c}
II	11.2	10.5	12.4	11.9	15.2	12.2
III	19.7^{a}	15.5	19.7^{b}	13.5^{ab}	16.0	16.8^{c}
IV	12.4	15.1	16.6	17.9	15.1	15.4
Mean	13.7	13.2	14.9	13.7	14.1	
Composition 2						
I	12.7	10.7	14.1	12.6	13.1	12.6^{a}
II	11.9	12.0	10.1	9.8	11.6	11.0^{bc}
III	19.4	18.3	18.5	15.7	16.6	17.7^{ab}
IV	17.6	16.2	20.3	15.6	15.2	16.9^{c}
Mean	15.4	14.3	15.7	13.4	14.1	
Composition 3						
I	7.7	9.4	10.7	9.4	8.6	9.1^{ef}
II	11.4	13.5	17.1	13.7	15.4	14.2^{g}
III	17.4^{ab}	18.1^{c}	19.1^{d}	25.5^{a}	26.4^{bcd}	21.3^{eg}
IV	17.1	23.6	20.4	18.9	17.9	19.5^{f}
Mean	13.4	16.1	16.8	16.8	17.0	
Composition 4						
I	7.8	6.9	8.9	10.5	10.1	8.8^{cd}
II	12.3	11.1	13.3	14.0	14.0	12.9
III	17.8^{a}	19.0^{b}	14.9	11.7^{ab}	15.6	15.8^{c}
IV	16.9	17.6	20.5	18.0	15.5	17.7^{d}
Mean	13.7	13.6	14.4	13.5	13.8	
Composition 5						
I	9.4	7.7	9.4	8.9	9.1	8.9^{cd}
II	12.8	10.2	13.6	10.2	9.6	11.2
III	17.2	18.9^{a}	18.3^{b}	16.1	13.5^{ab}	16.8^{c}
IV	13.5	14.6	17.0	13.4	16.9	15.0^{d}
Mean	13.2	12.8	14.5	12.1	12.2	
Composition 6						
I	8.5	7.1	8.4	9.3	10.9	8.8^{a}
II	8.2	11.3	11.9	11.3	12.8	11.1
III	13.4	16.3	17.0	17.8	12.7	15.4^{a}
IV	12.5	15.4	12.9	12.8	15.5	12.9
Mean	10.6	12.5	12.5	12.8	13.7	

Note: Standard errors range from 0.8 to 2.7. Mean distances in either a row or a column with the same superscript letter are significantly different at $p < 0.05$.

Table 4. Analyses of variance results (*F* values) for distance data for each composition as a function of participant group and version.

Source	df	Composition					
		1	2	3	4	5	6
Group (A)	3, 80	4.72*	5.31**	8.92**	4.80**	4.12**	3.10*
Version (B)	4, 320	0.68	0.65	1.92	0.42	0.46	1.13
$A \times B$	12, 320	2.80*	1.72	4.01**	2.96*	2.71*	0.90

$^{*}p < 0.05$, $^{**}p < 0.01$.

of the balance centers of altered versions from those of the originals were reliable only for participants trained in design. As seen in table 3, shifts were significantly greater for these participants when the largest area was red or blue than when it was yellow in certain versions of compositions 1, 4, and 5. In the case of composition 3, the balance center was shifted to a significantly greater extent when the largest area was red or blue than when it was yellow.

We next determined whether shifts in assigned balance centers between altered versions were significant as a function of composition and participant group. We computed, by participant, the Euclidean distance between the balance centers of each pair of the five altered versions of each composition. That is, for each participant we computed the distance between his/her assigned centers for version pairs ii and iii, ii and iv, ii and v, ii and vi, iii and iv, iii and v, iii and vi, iv and v, iv and vi, and v and vi of each composition. Distances were again expressed as a percentage of the total display width. Table 5 presents the average distances between the balance centers of the set of altered versions for each composition by participant group. A 4 (participant group) $\times$ 6 (composition) mixed unweighted means ANOVA was performed on these data; participant group was a between-subjects factor and composition was a within-subjects factor. A significant main effect was obtained for participant group ($F_{3,79} = 1.19$, $p < 0.001$) but neither the main effect for composition ($F_{5,380} = 1.97$, ns) nor the interaction ($F_{15,380} = 1.11$, ns) were significant. As shown in table 5, follow-up analysis (Tukey HSD) revealed that the average distance between the assigned balance centers of altered versions and those of the original compositions was significantly greater for the design-trained participants in experiment 1 than it was for the three groups of untrained participants; average shifts in the locations of balance centers between altered versions were not significantly different among the untrained participants. Informal examination of the distance data for the design-trained participants showed that the greatest shifts in balance centers consistently occurred between altered versions in which the largest color area was yellow as contrasted with either red or blue. For example, shifts in balance centers between composition 5 versions ii and vi, iv and v, and iv and vi were, on average, 10.4%, 11.8%, and 11.9% of the display field, respectively; the average shift for the other seven pairs of altered versions was only 4.8%.

Table 5. Average distances (percentage of picture display field) between the assigned balance centers of all pairs of the five altered versions for each composition for the four groups of participants. Participant groups: I, untrained participants in experiment 1a; II, untrained participants in experiment 1b; III, design-trained participants in experiment 1b; IV, untrained participants in experiment 2.

Group	Composition						Row mean
	1	2	3	4	5	6	
I	3.4	4.0	2.2	3.6	3.7	1.7	3.1[a]
II	4.7	4.1	3.7	3.3	3.6	4.5	3.9[a]
III	8.5	5.2	7.0	4.7	7.3	6.2	6.5[b]
IV	4.7	3.5	6.1	3.6	2.6	3.0	3.9[a]
Mean	5.3	4.2	4.8	3.8	4.2	3.8	

Note: Standard errors range from 0.22 to 0.56. Row means with different superscript letters are significantly different at $p < 0.05$.

3.2.3 *The relationship between the perceived weight of a composition's color areas and the location of its perceived balance center.* The final analyses were performed to determine if a change in the perceived weight of the color areas of a composition resulted in a significant shift in its perceived balance center. Recall that significant differences in weight were observed for area 1 (the largest color area) as a function of its color for four of the six compositions. As shown in table 1, when area 1 was yellow in versions v and vi of compositions 1, 2, and 4 and in version vi of composition 5, participants judged the weight of area 1 to be significantly lighter than when red in the original (version i). For each of the seven stimuli mentioned, we identified those individuals from among the sixty participants of experiment 1 who assigned the same rating to area 1 when yellow in its altered version and red in the original; those who rated area 1 lighter by 1 point on the 10 point rating scale when yellow than when it was red; and those who rated area 1 lighter by 2 or more points when it was yellow than when it was red. Because the balance center of a composition is determined by the distribution of its structural weight about the pictorial field, as explained above, it was predicted that greater differences in the perceived weight of area 1 when it was red compared with when it was yellow in each of the seven compositions should be associated with greater differences between the balance center of the original and that of its altered version. This hypothesis was tested separately for each of the seven original–altered stimulus combinations previously listed with a 1×3 (differences in weight: 0, 1, 2) between-subjects unweighted means ANOVA performed on the distance data summarized in table 6. This table contains the average distance between the assigned balance centers of an original composition and one of its altered versions as a function of the difference in perceived weight of color area 1. As shown in the table, the shifts in the location of the assigned balance centers for six of the seven altered versions were greater when area 1 had been rated 2 or more points lighter when yellow than when red than the shifts perceived by participants who gave area 1 comparable ratings for the two colors. However, analyses revealed that this tendency was reliable for only two stimuli: for composition 1, version v; and composition 2, version v (see table 6).

Table 6. Average distance (percentage of picture display field) between the balance center of an original composition and one of its altered versions as a function of the difference in perceived weight of color area 1. 0, 1, and 2 relate to difference in perceived weight of area 1 between original and altered version: 0, no difference; 1, area rated lighter in altered version by 1 point on the 10 point rating scale; 2, area rated lighter in altered versions by 2 points.

Stimuli	Mean distance between balance centers of original and altered versions/%			F	df	p
	0	1	2			
Composition 1—version v	8.3[a]	15.1	18.0[a]	4.16	2, 38	0.024
Composition 1—version vi	10.6	11.4	14.8	1.25	2, 40	
Composition 2—version v	9.9[a]	14.5	18.8[a]	3.94	2, 42	0.028
Composition 2—version vi	11.6	11.8	9.8	0.35	2, 44	
Composition 4—version v	15.2	14.5	18.8	1.95	2, 43	
Composition 4—version vi	11.9	14.8	17.5	1.29	2, 44	
Composition 5—version vi	9.7	11.8	13.1	0.39	2, 44	

Note: Standard errors range from 0.5 to 2.8. Means in a row with the same superscript letter are significantly different at $p < 0.05$ (Tukey HSD).

3.3 *Discussion*

The locations of the perceived balance centers for the original versions of compositions 1, 4, and 5 were concentrated in the center of the pictorial field; those for compositions 2 and 3 were aligned with their diagonal axes, and those for composition 6 were aligned with the horizontal axis. This was the case for both design-trained and untrained participants who responded to images seen on a computer screen and for those participants who saw the stimuli projected to actual size. The fact that the balance centers were perceived to be located at the center or along a central axis of the compositions indicates that the pictorial elements of each original composition are arranged in a balanced way within the structural organization of each composition, as intended by the artist. These findings support our selection of Mondrian's artworks for use as pictorial stimuli that are structurally balanced. Furthermore, although, as stated earlier, this research was not designed to test the visual correctness of Mondrian's paintings, the present findings provide support for the contention by art theoreticians that Mondrian, who employed no calculation or measuring when painting this series of works, achieved 'by eye' the optimization of balance he desired in his compositions (eg Schapiro 1995).

The finding that the perceived balance centers of the altered versions were scattered across the pictorial field to a greater extent than was the case for the original compositions suggests that rearrangement of colors in the altered versions produced structural organizations that were less well-organized (ie less balanced) than those of the originals. Data suggest that the effects of the color manipulations were much more perceptually salient to the design-trained than untrained participants in experiments 1a and 1b. This assertion is based on the fact that observed differences between balance centers of the originals and their altered versions were much greater across the entire stimulus set for design-trained than the untrained groups of subjects. Additionally, shifts in the locations of balance centers differed reliably among altered versions of four compositions for the design-trained participants, whereas no significant shifts were observed among altered versions for the three groups of untrained participants (see table 3). Design-trained participants also exhibited significantly greater shifts in the locations of balance centers among altered versions than all three groups of untrained individuals (see table 5).

Finally, distributions of balance centers of the originals and their altered versions were found to be very similar in nature between all participants who responded to computer images of the stimuli in the first experiment and those who saw the compositions in actual size in the second experiment. This can be seen in the plots presented in figure 2 and in the shift of balance center data reported in table 3. Thus, it appears that the induced structural framework that helps determine the role of each element within the balance system of the compositions studied did not differ as a function of the size of the image seen. This finding is taken as evidence of the ecological validity of results obtained from participants who responded to computer images of the stimulus set.

4 General discussion

The present findings demonstrate the existence of a color–area–weight relationship among color triads in abstract displays and the influence of this relationship on the perceived balance structure of the compositions. As mentioned, in previous investigations of the influence of color on spatial balance participants have had to respond to color pairs that varied in hue, value, and chroma. These studies have consistently found that the major determinants of color weight are chroma and value, and that color weight is relatively independent of the hues involved (eg Alexander and Shansky 1976; Morris and Dunlap 1988b). McManus et al (1985) reported that the major determinants of balance in their stimulus displays, which contained either one or two colored squares, was the position of the object in the field, and that the size and color of the squares were of lesser importance. In contrast to the limited contribution of hue to color balance reported in these investigations, in the present study hue was found to significantly influence balance within displays containing color triads. This suggests that a comprehensive understanding of the contribution of hue to spatial color balance may require the use of more complex stimuli similar to those used in the present study. Future experimenters must, however, address the limitations of the present study by investigating in a systematic fashion the combined contribution to color balance of the hue, value, chroma, and size and location of several colored areas within a display.

The present findings also demonstrate that observed differences in the perceived weight of the color areas in the abstract compositions influenced participants' perception of the structural organization of the compositions. This assertion is based on the fact that the perceived balance centers of the altered versions were scattered across the pictorial field to a greater extent than was the case for the original compositions. Furthermore, significant shifts in the locations of the assigned balance centers between the original and altered versions of the compositions were observed for both design-trained and untrained participants in experiment 1. Additionally, there was a tendency for shifts in the locations of the assigned balance centers between an original and its altered versions to be greater when differences in the assigned weight of area 1 in the two versions were greater. Taken together, these findings support the assertion that color is a major contributing factor to the balance structure of abstract compositions. However, McManus et al (1985) found no evidence that colored pictures of representational works of art have consistently different balance points than do black and white versions of the same pictures. Research by Locher (2003) suggests that McManus et al's observation may reflect the way individuals look at and think about abstract as compared to representational works. Locher found that when art-untrained individuals were asked to discriminate between a reproduction of a balanced painting by a renowned artist and less-balanced versions of it, which had been experimentally altered and perturbed, participants' reactions to abstract works were based predominately on the structural organization of the compositions, whereas they reacted to the beauty and realism of representational works and paid less attention to their structure. Taken together these findings suggest that a comprehensive understanding of the nature of color balance in complex displays may require investigations that include yet another factor—the stylistic characteristics of a picture.

With respect to the influence of training in the visual arts on viewers' sensitivity to color balance in relatively complex visual displays, the findings of the present study are mixed. Design-trained and untrained participants in experiment 1 were in good agreement as to the perceived weights of the large color area in different versions of five of the six compositions. This suggests that the color–area–weight relationship in the stimuli studied was salient to viewers regardless of their training in the visual arts. This finding replicates Locher et al's (1996) observation that design and museum professionals were in agreement with individuals untrained in the visual arts as to the weights of the structural components underlying the balance organization of abstract and representational paintings. However, the fact that, in experiment 1 of the present study, only trained participants perceived differences in the weights of area 1 and area 2 among the various versions of composition 3 suggests that expertise may be required to detect shifts in perceptual weight when large disparities exist in the size of the colored areas. Furthermore, reliable shifts in the locations of the balance centers among different altered versions of four compositions were observed for the design-trained participants in experiment 1b. No reliable shifts between versions were observed for any of the untrained participants in experiments 1 and 2. Thus, it appears that, although one does not need training in the visual arts to respond to the color–weight–area relationship among compositional elements, to perceive the influence of this relationship on the overall balance organizational structure of a composition does require training. This finding is comparable with observations made by Locher et al (1999b) that design-trained individuals, but not untrained ones, were able to discriminate balanced abstract compositions and representational compositions from experimentally manipulated less well-organized versions of each work.

Finally, the general location of perceived balance centers and the nature of their distributions in the different compositions were very similar for all participants in experiments 1 and 2. This suggests that the perceived structural organization of the compositions studied did not differ with respect to their spatial and temporal characteristics as a function of the size of the image seen. This finding is in accord with studies of the presentation format of paintings by renowned artists conducted by Locher et al (1999a, 2001). They investigated the comparability of art-trained and untrained viewers' responses to slide-projected and computer-generated images with those obtained from individuals experiencing the originals in the galleries of the New York Metropolitan Museum of Art. Locher et al found that participants' evaluations of the pictorial qualities of the artworks, such as the complexity, density, scale, and symmetry of the compositions, did not differ reliably as a function of presentation format.

In conclusion, the findings provide preliminary support for the existence of a color – area – weight relationship among color triads in abstract displays and for the influence of this relationship on perceived color balance. This research has shown that a number of stimulus properties and viewer characteristics must be taken into consideration in future investigations of color balance. Whether the precise quantitative nature of the color-strength – area relationship between color triads and the underlying mechanism responsible for it can be experimentally determined remains to be seen. For, as Pope (1944) observed many years ago, there are so many intangible factors associated with color perception in the way of individual preferences due to associations, traditions, and other factors that any exact mathematical calculation of harmonious color combinations will be very difficult to achieve.

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