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The role of balance as an organizing design principle underlying adults' compositional strategies for creating visual displays

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Abstract

This study had two interrelated purposes, namely, to determine if balance influences the way adults create visual displays and to subject theoretical notions of pictorial balance to experimental scrutiny. Adult volunteers made four designs, one each from circles, squares, rectangles, or leaves of different sizes. A videotape recording of the development of each design from start to completion was used to create a digitized record of its image at 10% intervals of the time taken for its completion. It was found that, regardless of element type or phase of construction, the center of a design was closely aligned with the geometric center of the pictorial field demonstrating the power of the center of a square field to function as an "anchor" or balancing point about which a design's structural skeleton is organized. The ordering strategy used by participants to organize the elements of a composition about its balancing center was influenced by their shape characteristics and orientation potential. Structural weight was evenly distributed (balanced) about the center of the circle designs throughout their construction; an imaginary horizontal–vertical grid served as the structural skeleton for the creation of designs composed of squares and rectangles, and participants manipulated directionality of leaf elements to create an organized global design within the pictorial field. Finally, evidence of the visual salience of dynamic balance is provided by the finding that viewers were able to perceive subtle differences measured quantitatively in the distribution of physical weight about

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the axes of balanced compositions. Theoretical speculation concerning the nature of pictorial balance is discussed in light of the present findings.

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1. Introduction

In his treatise on design and expression in the visual arts, Taylor (1964) states that "a work of art is more than an artistic equilibrium; but it is always committed to being at least that. A work which achieves less is artistically incomplete. A work which is committed to achieving less has not the status of art at all" (p. 28). For centuries artists and writers on Western art have asserted, like Taylor, that balance is the primary design principle guiding the distribution of the various elements within a work (see, e.g., Arnheim, 1988; Bouleau, 1980; Kandinsky, 1979; Weismann, 1976). According to this view, balance is necessary because it unifies the structural elements of a visual display into a cohesive narrative statement thereby creating the essential integrity or meaning of the work.

A pictorial configuration is said to be balanced when its elements and their qualities are poised or organized about a balancing center so that they appear anchored and stable. The simplest and most obvious sort of balance is the phenomenon of symmetry. A symmetric display is one in which there is an exact one-to-one correspondence of components about a center line or a central point. For example, when one half of a composition appears as the "mirror image" of the other, it is said to exhibit a formal type of balance called bilateral symmetry.

Far more complex and interesting are objects and images whose elements are grouped or organized asymmetrically about a balancing center in such a way that their visual forces compensate one another. This type of equilibrium is referred to as dynamic balance. Studies of the relationship between aesthetic preference and the organizational structure of paintings and pictures (e.g., Beaumont, 1985; Freimuth and Wapner, 1979; Mead and McLaughlin, 1992) have established that there are three major stimulus features that contribute to a composition's *perceived* balance. They are: (a) the distribution of "weight" about the axes of the pictorial field (especially about the vertical and horizontal axes), (b) cue directionality (principally with respect to left–right lateral organization), and (c) the location of the area of principal interest or greatest weight. Books on composition present a variety of techniques by which an artist can control these three relations in pictorial space to achieve balance (e.g., Bearden and Holty, 1969; Bouleau, 1980).

Empirical support for the theoretical principles concerning the nature of pictorial balance found in these writings has been reported by Locher et al. (1996) and McManus et al. (1985). Participants in the research of Locher et al. identified the balancing centers of reproductions of 20th-century paintings and then assigned "weights" to the pictorial features which contributed to the location of the balancing center of each work. They found that design and museum professionals and individuals untrained in the visual arts were in good agreement as to the location of the balancing center of the paintings and the location in the field of the areas of visual weight which formed the structural framework underlying the balance organization of a painting.

McManus et al. (1985) had subjects judge the balance center of reproductions of works of art by placing a fulcrum beneath each composition at the point at which the painting would "hang level" on the fulcrum. Participants, who had no special training in art, showed good agreement as to the location of the balance centers. Additionally, McManus et al. reported that the location of the balance center of a picture differed from that of a "chopped" version of it created by removing a peripheral portion from one end of the original. Because the arrangement of elements within both versions remained the same, they concluded that no one pictorial feature (or features) was the origin or determinant of balance. Rather, participants' judgments arose from a global percept based on an integration of stimulus information across the entire picture field.

Not only is balance an important design principle in the practice of art at the highest level, as mentioned above, it has been found to play a similarly dominant role in the production of drawings by children. For example, Golomb (1987b) investigated development of the graphic planning strategies of children ranging in age from 3 to 14. She observed that young children's drawings are characterized by arrangements of figures that are arbitrarily dispersed across a page. By approximately age 9, Golomb found that children create order among the elements of a pictorial space using strategies that she described in terms of two organizing principles, namely, an alignment of figures within a horizontal–vertical grid, and a centric system that privileges the center of the display and leads to various forms of complex symmetry and balance. These strategies remained unchanged through age 14, the oldest age group included in Golomb's study. Using the assessment instrument employed by Golomb (1987b), Golomb (1987a) observed that alignment and symmetry/balance graphic strategies also dominated the drawings of severely emotionally disturbed children between the ages of 11 and 14. Golomb (1987a) concluded that development of these strategies occurs independently of emotional disturbance and remains relatively unaffected by psychopathology.

Empirical evidence that balance continues to play an important role in the production of visual displays into adulthood has not appeared in the literature. The present research sought such evidence. Each adult participant constructed four designs within a square pictorial field, one each from four different types of elements: circles, squares, rectangles, and leaves. Videotape recordings of the development of each design from start to completion were used to answer the principal question addressed by this research, namely, does balance serve as a dominant compositional strategy when adults create visual displays, and, if so, at what point in compositional development does it appear?

To our knowledge, all previous studies of the role of symmetry and balance in composition have determined their presence in participants' pictorial compositions qualitatively by observation. We report a technique, explained in detail later, that enabled us to evaluate quantitatively three structural characteristics of our subjects' compositions that contribute to balance and report the degree to which a given design is balanced as it was constructed. These properties include the location of the balancing center of each design; the distribution of physical (structural) weight about its axes, and the alignment and directional qualities of its component elements.

In addition to providing a quantitative account of adults' compositional strategies, the present investigation sought to subject theoretical notions of balance to experimental scrutiny. It was our goal to provide the types of "physical evidence" that Arnheim (1974, 1988) and others assume underlie their philosophical writings on these issues.

Finally, having quantitative measures of the physical balance of participants' designs made it possible for us to examine another issue not previously investigated, namely, the sensitivity of the human perceptual system to variations or degrees of balance in visual displays. To this end, we assessed the relationship between the physical balance of participants' designs and ratings of the perceived balance of the designs made by a different group of subjects.

2. Method

2.1. Participants

The 13 paid participants (6 females and 7 males) were Industrial Design Engineering students who had completed their first year of study at Delft University of Technology. First-year students in this program start their training as a homogeneous group in that they lack design experience. The focus of their lectures, form exercises, and design projects is the role of design knowledge in relation to the creativity of design solutions. Thus, participants in the present study are considered novice design students and the compositional strategies used by them to construct visual displays in this research were not believed to be the result of direct instruction.

2.2. Stimulus materials and apparatus

Each participant was asked to create four designs, one each from a set of either nine circles, squares, rectangles, or leaves. Each set of shapes consisted of three large, three medium, and three small forms cut from sheets of low-luster black polystyrene 1.5 mm in thickness. Circles had diameters of 5.6, 3.9, and 2.8 cm. The squares measured 5.0, 3.5, and 2.5 cm on a side. The aspect ratio for the rectangles was 2:3; they measured 4.0×6.0 cm^2, 2.8×4.2 cm^2, and 2.0×3.0 cm^2. Leaves were 6.5, 4.6, and 3.2 cm from tip to stem and 5.9, 4.1, and 2.9 cm at their widest point. Given these dimensions, the areas of the small and medium shapes of each element type were 1/4 and 1/2 the area of the large shape, respectively. In addition, shape dimensions produced comparable areas for all large, medium, and small shapes, namely, 24 cm^2, 12 cm^2, and 6 cm^2, respectively.

The apparatus used to videotape compositional development of each design from start to finish is illustrated in Fig. 1. Participants sat at a table into which a 30 × 30 cm^2 display field had been cut. A piece of clear plastic was placed in the opening and surrounded by a black paper frame 2.5 cm in width. The surface of the display field, frame, and surrounding table top was covered with a 50 × 50 cm^2 sheet of transparent technical drawing paper. This material gave the display field a light grey appearance on which participants arranged the black shapes and it reduced somewhat the contrast of the black frame.

The contents of the display field were reflected on a mirror positioned at a 45° angle directly below it and continuously recorded on tape by a video camera lens suspended below the table in line with the mirror. This set-up provided a high-contrast image of all shapes constituting the design unobstructed by a participant's hands as he or she arranged the elements on the display field.

The number and size of shapes employed, the size of the display field and the thickness of the frame surrounding it were chosen following extensive informal investigation of various combinations of these factors. The principal concern in deciding upon the properties of shapes and the display field used was that the perceived character of the shapes not be unduly influenced by what surrounded them. As is frequently mentioned in treatises on pictorial composition (see, e.g., Arnheim, 1988;

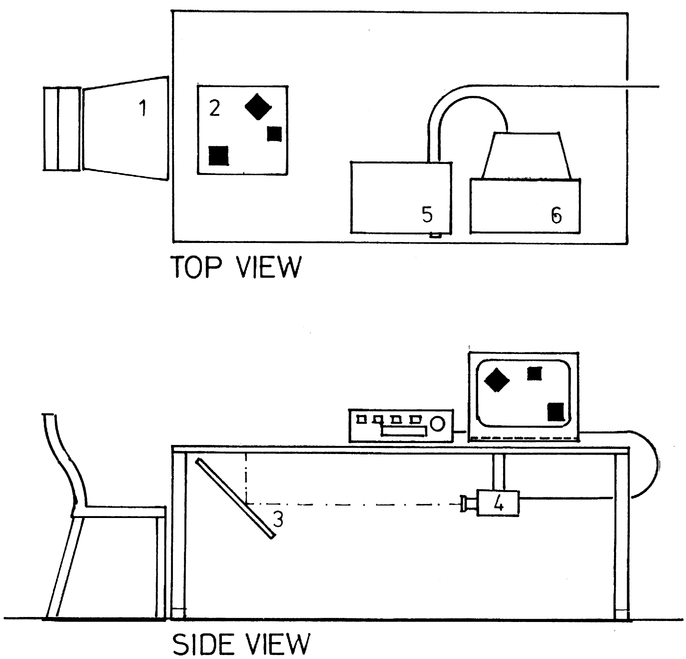

Fig. 1. Top and side views of the apparatus used to videotape compositional development of participants' designs. Participants sat (1) at a table and created each design on a display field (2), the contents of which were reflected on a mirror (3) positioned at a 45° angle directly below it and in line with a video camera lens (4). Compositional development of each design from start to finish was videotaped (5, 6).

Taylor, 1964), the shape and size of a pictorial field, as well as the frame that encloses it, are conditions of all appearances that fall within it. It should also be noted that the shapes were selected to provide different potentials for orientation alignment of the elements within the designs, an issue discussed later in this paper. Furthermore, three shapes of each size were employed, rather than an even number, to make it impossible for participants to create a design that was symmetric about all four axes.

2.3. Procedure

Participants read (in Dutch) the following instructions: "Your task is to create four different designs. Each design will be constructed using nine identical shapes of different sizes like those placed next to the display area in front of you. Make a composition that you find both interesting and pleasant. You may begin with one or more shapes or with all nine, but your final design must include all nine shapes. The only restriction on your compositional strategy is that one shape may not overlap another shape. Take the time you need to arrange and rearrange the shapes within the frame to create a display you find both interesting and pleasing."

The order of element types used to create the four designs was counterbalanced across subjects. The nine shapes were arranged randomly to the left side of the display field (outside of the frame) at the beginning of each task. Participants indicated the start of each trial by moving a subject identification number from the center of the display field to an area outside of its frame. To indicate that the composition was completed, they placed the identification number over the design. The removal and reappearance of the number, visible on the videotape, marked the start and finish of the compositional process.

2.4. Data preparation

A Watford Electronics real-time video digitizer was used to create a digitized record of the development of each design. For each participant's four designs, this was accomplished in the following manner. First, the videotape signal for a given design was converted by the digitizer into a sequence of display frames which were stored in working memory of an Acorn Archimedes computer. The image of the design at 10% of its completion time was then called from the digitizer's memory and displayed on the computer screen. Next, co-ordinates of the location and orientation (except for circles) of each shape in the field were determined interactively from the image by indicating prominent landmarks of the shapes displayed on the monitor. The co-ordinates were then stored in memory. Procedures employed captured the orientation of squares, rectangles, and leaves. When necessary, contrast enhancing and thresholding display routines were applied to imaged shapes to clarify perimeter features before measuring their position and orientation.

For each design this process was repeated at 10% intervals of the total time taken for its completion (i.e., 10%, 20%, 30%, etc. to 100% – the completed design). So, for example, if 230 display frames were created for a design, the contents of frames 23, 46, 69, 92, 115, 138, 161, 184, 207, and 230 were digitized and stored. Fig. 2 presents the sequence of 10 computer images for two designs, one composed of circles and the other of leaves.

3. Results

3.1. A descriptive account of participants' compositional strategies

Inspection of the videotape records revealed that participants almost always used both hands to slide shapes from one display location to another while creating their designs. Most often two shapes were repositioned simultaneously. Additionally, participants rearranged the shapes almost continuously during compositional development; relatively few periods of inactivity of the hands were observed.

Each participant was consistent with respect to the strategy he or she used to create the four designs. Four subjects began by rapidly placing the nine shapes in the field and then rearranging them until the design was deemed finished. For these

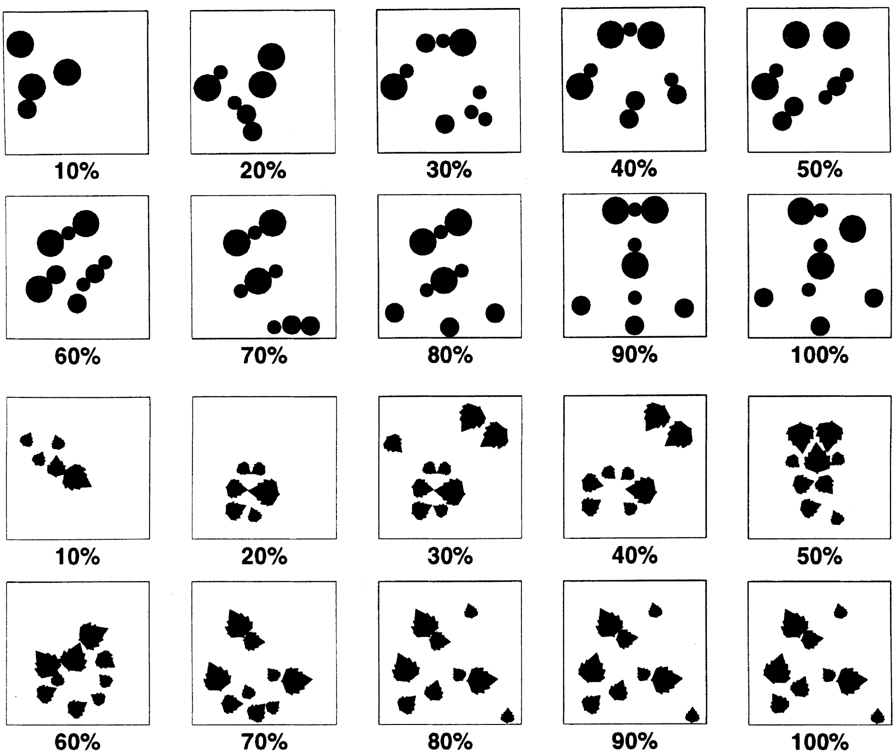

Fig. 2. Computer images of a circle and a leaf design at 10% intervals of the time taken for their completion.

subjects all nine shapes appeared in the first digitized image of each design. The other nine subjects used a strategy like that shown in Fig. 2. Specifically, they began construction of each design with a few shapes and proceeded by adding one or two elements at a time, adjusting the overall organization with the addition of each shape. When creating a design out of circles, squares, rectangles, or leaves, this process lasted, on an average, the first 31%, 44%, 36% or 31%, respectively, of total composition time (SDs = 4.3%, 5.8%, 4.5%, and 4.7%, respectively). A one-way repeated measures analysis of variance (ANOVA) revealed that this strategy lasted significantly longer for squares than for circles or leaves, $F(3,36) = 3.01$, $p < 0.05$; Tukey HSD = 11.2, $p < 0.05$. After all shapes had finally been placed in the field, participants proceeded to rearrange them into the completed design composition.

The time taken by participants to complete the designs was not influenced by the type of element used. On an average, participants spent 142, 155, 168, and 132 s (SDs = 80, 74, 98, 37 s) completing designs composed of circles, squares, rectangles, or leaves, respectively. A one-way repeated measures ANOVA performed on these data yielded a non-significant $F(3,36)$ value of 0.77.

3.2. Location of the balancing centers within the pictorial field

A visual display has three centers, namely, a physical or geometric center, a structural balancing center, and a perceived center. The structural balancing center is located at that point within a display about which there is an equal distribution of the physical weight associated with its components. As such, the balancing center functions as the hub or stable base of the compositional structure. In addition to a structural balancing center, every display contains a perceptually induced phenomenal balance center which is not usually explicitly marked in the composition by a structural feature or element.

In this section we contrast the location of the physical and structural balancing centers of participants' designs. It was expected that the two centers would be closely aligned. This prediction was based on the fact that the shape of the enclosure or pictorial field on which participants constructed their designs was square. As Arnheim (1988), Bouleau (1980), Taylor (1964), and others have noted, the location of the balancing center of a square field is primarily determined by the crossing of its four axes, namely, the two paralleling the edges and the two diagonals connecting the corners. Stated another way, the centric symmetry of the square format points to the geometric center of the field as its balancing center.

The co-ordinates within the pictorial field of the structural balancing centers of the four designs created by each participant were calculated at each of the ten consecutive construction time intervals mentioned earlier. The balancing center of a given design was defined as the point within the design about which there is an equal distribution of weight associated with its nine elements. Stated another way, it is the "center of the gravity" of black space created by the elements. Fig. 3 presents the shift in the structural balancing center of each design within the pictorial field as it was completed. The ten data points used to generate each line are the balancing centers of one design calculated at each of the 10 construction time intervals. The

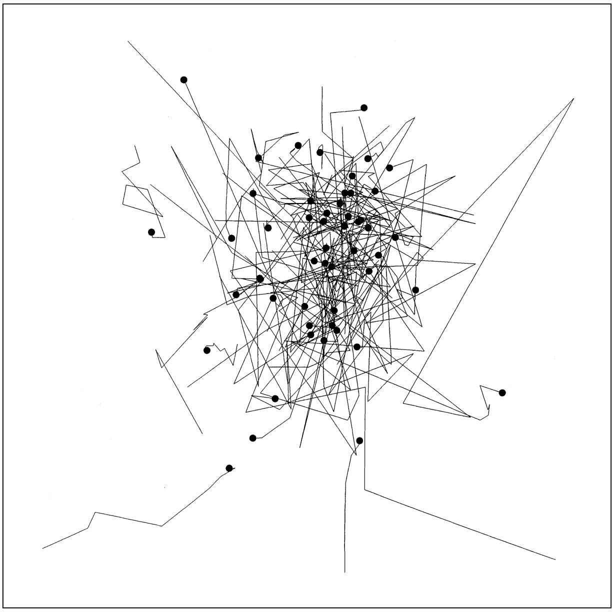

Fig. 3. This figure presents the shift in the structural balancing center of each design within the pictorial field as it was completed. The ten data points used to generate each line are the balancing centers of one design calculated at each of the 10 construction time intervals. The black dots represent the balancing centers of the 52 completed designs.

black dots represent the balancing centers of the 52 completed designs. The location within the field of the balancing center for each of the 13 circle, 13 square, 13 rectangle, and 13 leaf designs are seen in Fig. 4.

What is readily apparent when one examines these figures is that, regardless of element type or phase of construction, the center of a design was relatively closely aligned with the geometric center of the pictorial field. We measured the distance (ignoring direction) between the balancing and physical centers of each completed design created within the 30×30 cm^2 pictorial field. This distance was, on an average, 2.47, 3.67, 3.02, and 4.04 cm (SDs $= 1.87$, 2.30, 2.62, and 1.87 cm) for circle, square, rectangle, and leaf designs, respectively. These values do not significantly differ, as determined by a one-way repeated measures ANOVA performed on the absolute values of the distance data, $F(3,36) = 1.11$ ns.

It can be seen in Fig. 3 that the balancing center of most designs shifted somewhat within the pictorial field during construction, and that the balancing centers of the final versions appear to be, on an average, nearer to the physical center than in earlier versions. Statistical comparisons of the distance between the geometric and balancing centers of the designs across construction time intervals revealed that the differences do not, in fact, reflect significant changes in the location of the balancing center within the field for any element type. For example, this distance was, on an average, 3.05, 2.84, 3.36, and 3.75 cm (SDs $= 2.01$, 2.32, 2.65, 1.63 cm) for the circle,

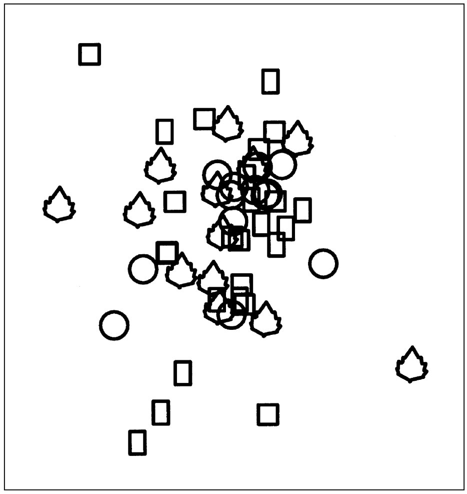

Fig. 4. The location within the pictorial field of the balancing center for each of the 13 circle, 13 square, 13 rectangle, and 13 leaf designs.

square, rectangle, and leaf designs, respectively, at 40% completion, the time by which all nine elements had been placed in the field. None of these values differed reliably from the corresponding means for the completed versions listed above when a 2 (completion interval – 40% and 100%) $\times$ 4 (element type) repeated measures ANOVA was performed on these data. Neither the main effects of completion interval, $F(1,84) = 1.89$ ns, and element type, $F(3,84) = 0.96$ ns, nor their interaction, $F(3,84) = 1.01$ ns, were statistically significant.

Furthermore, the distances between the two centers at 40% and 100% completion for the circle, square, rectangle, and leaf designs are significantly positively correlated, rs $(11) = 0.84$, $p < 0.0001$; 0.66, $p < 0.007$; 0.71, $p < 0.003$, and 0.57, $p < 0.02$, respectively. These findings provide strong empirical evidence of the power of the physical center of a square display field to function as an "anchor" or balancing point about which a design's structural skeleton is organized.

It should also be noted in Figs. 3 and 4 that not all of the balancing centers are located at or near the geometric center, and those that are not tend to be to the left rather than to the right side of the physical center. For such compositions, it follows that participants placed more elements (structural weight) in the left side of the pictorial field than in the right side. We attribute this left-side organizational bias to a methodological shortcoming, namely, the fact that the elements were placed to the left of the pictorial field at the start of all trials. Examination of the videotape records revealed that many participants whose designs exhibited a left-side bias slid a few elements onto the left area of the field with their left hand at the start of design construction. In such cases, completion of a design frequently involved "elaboration" of its initial structural organization established in the left field, that is, the left-side weight distribution bias was maintained during construction. To avoid this potential bias in future studies of this type, design elements should be randomly arranged to the right and the left sides of the display field prior to the onset of design construction.

3.3. Distribution of physical weight within the design

As previously mentioned, one of the most important structural properties contributing to the balance of a visual display is the distribution of physical weight within that display. Balance can be achieved by a one-to-one correspondence of components about a central axis, as with symmetric designs, or more dynamically, by an equality of structural weight about the axes of a design. This section reports the distribution of physical weight about the principal and intermediate axes of participants' designs as they were constructed.

We first examined the set of designs to determine the extent to which symmetry was used by participants to compose their designs. It was observed that one or more symmetric (or very nearly symmetric) arrangements emerged during the construction of 20 of the 52 displays completed by all participants. For example, in Fig. 2 it can be seen that the structural arrangement of the circle design at 90% completion was bilaterally symmetric about the vertical axis, as were most of the symmetric designs. Overall, however, only 62 (12%) designs included in the full set of 520 compositions appeared symmetric about any axis. It was concluded, therefore, that symmetry played a relatively minor role as a design principle for construction of the compositions.

Balance, of course, does not require symmetry. To determine whether participants' designs displayed dynamic balance, we calculated the percentage of physical weight associated with the elements in each design on both sides of eight axes running through the center of the pictorial field. These included the four principal axes of a square field, namely, the vertical and horizontal axes and the two diagonals connecting the corners, as well as the four intermediate diagonals located 22.5° between the principal axes. Fig. 5 presents the percentage of weight (the ordinate) to one side of each axis (the abscissa) for each of the 13 completed leaf designs. The mean for each axis is indicated by the short horizontal line drawn through its distribution. Percentages are shown for the areas to the right of the vertical axis; to the right of oblique axes positioned 22.5°, 45.0° and 67.5° from vertical; above the horizontal axis, and above the oblique axes 112.5°, 135.0°, and 157.5° from vertical.

As an example of how Fig. 5 is to be read, consider the bottom dot in the first column of the figure. This data point indicates that there was one participant who, in his completed leaf composition, had positioned 5% of the mass associated with the nine structural elements to the right of the vertical axis of the pictorial field, and the remaining 95% in the left side of the field. The opposite situation is reflected by the uppermost dot in the same column; this participant's final leaf composition contained approximately 90% versus 10% of its structural weight to the right and left of the vertical axis, respectively. (Note that some columns in Fig. 5 appear to contain fewer than 13 dots. In these cases several data points have very similar numerical values and therefore overlap each other in the figure.)

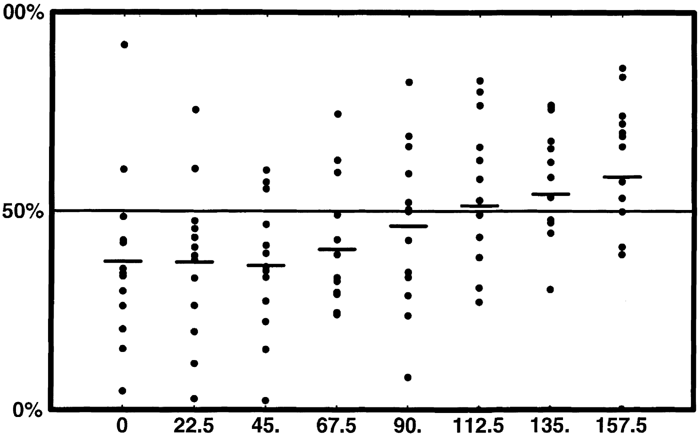

Fig. 5. This figure presents the percentage of weight (the ordinate) to one side of each axis (the abscissa) for each of the 13 completed leaf designs. The mean for each axis is indicated by the short horizontal line drawn through its distribution (percentages are shown for the areas to the right of the vertical axis; to the right of oblique axes positioned 22.5°, 45.0° and 67.5° from vertical; above the horizontal axis, and above the oblique axes 112.5°, 135.0°, and 157.5° from vertical).

Fig. 6 depicts the distributions of weight about the eight axes of the four designs completed by each participant at each of the ten construction time intervals. (Each graph in Fig. 6 is to be read like the one in Fig. 5.) What is readily apparent when one examines Fig. 6 is that participants showed wide variation in the way they distributed elements about the axes of their designs. The wide range of variability about the means for the various conditions makes statistical examination of group effects untenable. The group data do, however, provide insights into the nature of participants' compositional strategies.

First, as seen in Fig. 6, structural weight was rather evenly distributed about the eight axes of the completed circle designs. This indicates that most participants arranged the nine circular elements in a highly balanced configuration about the centers of the completed designs which were, as shown in Fig. 4, located close to the center of the pictorial field. Furthermore, it can be seen in Fig. 6 that a balanced organization emerged at the earliest stages of construction of the circle designs. An example of one participant's use of balance as the organizing principle to create a circle design is found in Table 1 which contains weight distributions about the four principal axes at each construction time interval for the circle design shown in Fig. 2.

With respect to the leaf, rectangle, and square designs, the data depicted in Fig. 6 show that participants did not, as a group, distribute physical weight within these compositions in a balanced fashion about the various axes of the square pictorial field at any time during construction. Rather, as will be shown in the next section, it was the unique shape characteristics of these elements which influenced the way participants arranged them within the designs.

Lastly, Fig. 6 illustrates the tendency, mentioned earlier, for some participants to have placed elements exclusively in the left side of the pictorial field at the start of

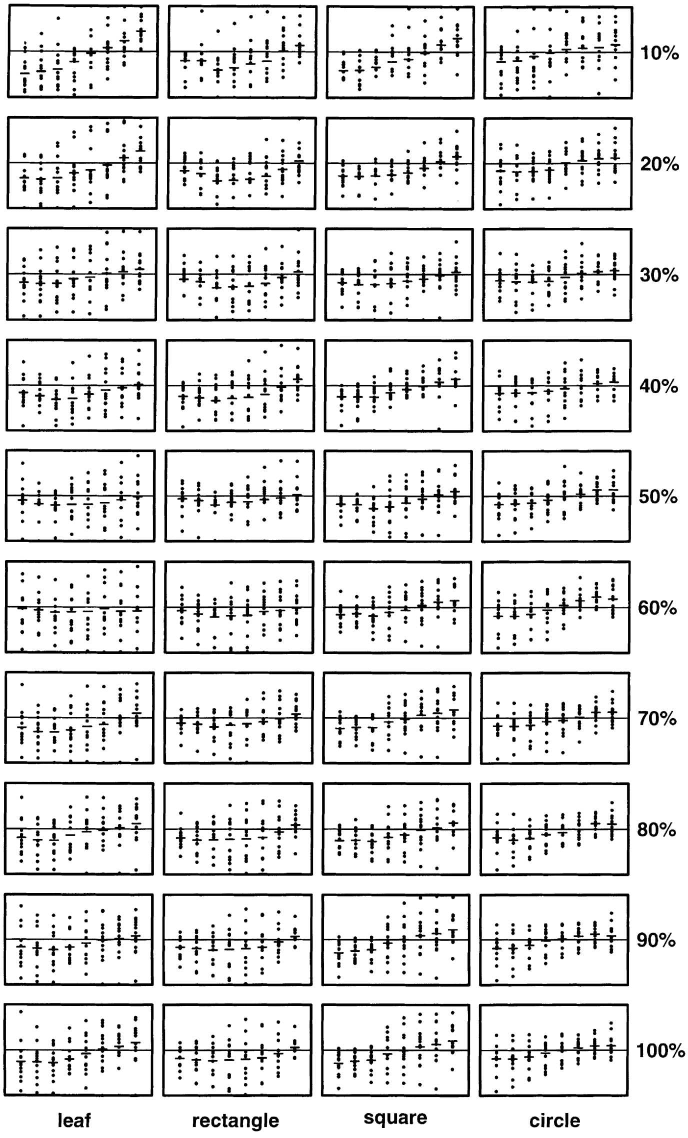

Fig. 6. The figure depicts the distributions of weight about the eight axes of the four designs completed by each participant at each of the ten construction time intervals. Each graph in Fig. 6 is to be read like the one in Fig. 5.

design construction. This is evidenced in the figure by the data points close to the bottom of the first column of the graphs in row 1 (10% completion time). Furthermore, our observation from the taped records that this left-side bias was maintained during design construction is manifest in the figure by the similarity in location of these data points in the graphs across construction time intervals.

Table 1
Percent weight distributions on both sides of four design axes at each construction time interval for the circle design shown in Fig. 2

Construction time intervals (%)	Axes							
	V		H		RD		LD	
	Side of axis							
	L	R	A	B	A	B	A	B
10	97	3	34	66	82	18	0	100
20	70	30	66	41	31	69	36	64
30	56	44	47	53	51	49	29	71
40	58	42	46	54	43	57	33	67
50	62	38	47	53	48	52	30	70
60	60	40	51	49	54	46	29	71
70	48	52	54	46	62	38	48	52
80	56	44	55	45	60	40	42	58
90	49	51	42	58	35	65	33	67
100	52	48	42	58	33	67	40	60

Note: V is vertical axis (0°), H horizontal axis (90°); RD diagonal axis 45° clockwise from vertical; LD diagonal axis 45° counterclockwise from vertical; L left of axis; R right of axis; A above axis; B below axis.

3.4. Spatial arrangement of elements within the designs

Thus far it has been established that the physical organization of circle designs is highly balanced with respect to the distribution of structural weight about the pictorial field axes. Participants did not, however, use the same strategy to establish order among square, rectangle and leaf elements. Rather, inspection of these compositions revealed that, at least for square and rectangular elements, participants' organizing strategies consisted of aligning elements on an imaginary horizontal-vertical grid. To confirm these qualitative observations, we quantified the extent to which square, rectangle, and leaf elements were aligned with the vertical, horizontal and oblique axes of the pictorial field.

Specifically, we computed the percentage of the elements (each weighted by its area) comprising each design that were similarly oriented (parallel) with one of the 4, 8, or 16 axes of the square, rectangle, and leaf designs, respectively. The number of axes per element type reflects the fact that their potential for orientation alignment within a field is limited by their rotational symmetries which are 90°, 180°, and 360°, respectively, and by our decision to include axes spaced at 22.5° intervals from vertical. An element was said to point in a direction consistent with a given field axis if the element's axis was parallel to an area extending from the center of the pictorial field to a compass distance 11.25° on either side of the field axis. The central axes of a square and the long central axis of a rectangle defined their orientations. The orientation of a leaf was defined as the direction of a line extending from its stem to its tip.

Table 2 presents the percentage of elements aligned with each axis for all completed square, rectangle and leaf designs. As seen in the table, 70% of the elements of completed square designs were aligned with the vertical axis and, simultaneously the horizontal axis; 19% with the main obliques (45° and 135°), and the remaining

Table 2
Percent of elements aligned with axes of the completed square, rectangle, and leaf designs

Square designs				
Axis orientation (°)	0	22.5	45.0	67.5
Percent (%)	70	6	19	5
Rectangle designs				
Axis orientation (°)	0	22.5	45.0	67.5
Percent (%)	51	4	4	0
Axis orientation (°)	90.0	112.5	135.0	157.5
Percent (%)	33	1	5	3
Leaf designs				
Axis orientation (°)	0	22.5	45.0	67.5
Percent (%)	5	6	3	6
Axis orientation (°)	90.0	112.5	135.0	157.5
Percent (%)	2	4	7	7
Axis orientation (°)	180.0	202.5	225.0	247.5
Percent (%)	15	10	7	1
Axis orientation (°)	270.0	292.5	315.0	337.5
Percent (%)	3	6	14	3

Note: Axis orientations are rotated clockwise from the vertical axis (0°).

11% were oriented in the direction of the other obliques (22.5°, 67.5°, 112.5°, and 157.5°). To an even greater extent than was the case for square designs, an imaginary horizontal-vertical grid served as the structural skeleton for the creation of the rectangle designs. As shown in Table 2, 84% of the rectangular shapes were aligned with these axes; the remaining 16% were oriented along the primary and secondary oblique axes. Clearly the organizing strategy favored by participants for the creation of square and rectangle designs was one that distributed component shapes in directions consistent with the horizontal and vertical pictorial axes. It should be noted that for approximately half of the subjects, this alignment strategy was combined with one that simultaneously imposed a relatively balanced distribution of structural weight about the axes of square and rectangle designs (see Fig. 6). Additionally, examination of the data for this directional dimension across construction intervals revealed consistent use of an alignment strategy from the start to completion of these designs.

Because leaf elements are capable of pointing in any direction, more dynamic designs can be achieved with them than is possible with square and rectangle elements. Participants took advantage of this orientation potential and created leaf patterns whose organizations do not adhere to the more "rigid" structural skeletons of the square and rectangle designs. This assertion is based on the finding that no more than 15% of the elements comprising the completed leaf designs were aligned with any one of the 16 field axes used for this analysis, as seen in Table 2.

To gain additional insights into the way participants manipulated leaf elements within the pictorial field, we calculated the degree to which they modified the dynamic quality (entropy) of leaf compositions during construction in the following manner. An entropy value was computed for each design by calculating the orientation

Table 3
Average entropy values (in degrees) for leaf designs at the ten construction time intervals

	Construction time interval (%)									
	10	20	30	40	50	60	70	80	90	100
M	66.68	55.84	48.31	53.02	54.36	42.45	40.38	59.63	62.26	62.08
SD	40.52	31.64	24.48	27.15	29.74	17.65	18.01	33.07	21.16	27.20

angle between every possible pair of leaves in a display [$n(n-1)/2$ angles for a display of n elements]. From this distribution of angles, the mean value was used as a measure of the degree of alignment of the shapes. Because the rotational symmetry of leaves is 360°, the maximal orientation angle between a pair of elements is 180°. This value is also the theoretical maximum for the entropy value for leaf elements, but it is only encountered for the average orientation angle in a design consisting of two elements. For compositions of more than two elements, not all pairs can simultaneously have this angle between them, so the entropy values for completed multi-element designs will be much less.

Mean entropy values (in degrees) for leaf designs at each of the 10 construction time intervals are presented in Table 3. As these data show, elements within leaf compositions not only varied in orientation, but the degree of entropy fluctuated during display construction. Specifically, entropy was high during the initial phases of construction; it declined to a lower point by the time a display was 60–70% complete, and then rose again as final adjustments were made to it. That these fluctuations are statistically significant was confirmed by results of a one-way repeated measures ANOVA performed on the entropy data for the 10 time intervals, $F(9,108) = 2.83$, $p < 0.05$; Tukey HSD = 21.48, $p < 0.05$. Specifically, it was found that entropy was significantly lower on an average at 70% completion than during the first construction interval (i.e., level 10%) or the last two intervals (*M*s = 40.4° vs. 66.9°, 62.3° and 62.1°, respectively). We speculate that these findings indicate that participants initially worked to organize the global structure of the leaf designs into a coherent composition of some sort and then introduced modifications in the design to give it a more aesthetic quality of the type suggested by the task which was to create an interesting and pleasing design. Such a compositional strategy appears to have been used by the participant who created the leaf design shown in Fig. 2. Note that manipulation of the field during the last two construction intervals involved adjustment of the design established at 70% of its completion.

3.5. The relationship between physical balance and perceptual balance of the designs

Having quantitative measures of physical balance as defined by weight distribution about axes of participants' designs made it possible to examine the relationship between the physical and perceived balance of the designs. Estimates of the perceived balance of the compositions were obtained in the following manner. The first author and four of his graduate students who were completing thesis projects involving balance perception, and were therefore very familiar with theoretical notions of balance, rated participants' compositions for perceived balance about each of the four principal axis of the square frame. Each rater evaluated a different random order of 378 of the full set of 520 compositions; eliminated were the 62 formally symmetric designs and the 80 compositions that contained fewer than nine elements. Each composition was reproduced within a 15×15 cm^2 square on a separate paper. Each design was evaluated for balance about its vertical, horizontal and two diagonal axes on a 6-point scale (1 = highly balanced; 2 = moderately balanced; 3 = somewhat balanced; 4 = somewhat imbalanced; 5 = moderately imbalanced, and 6 = highly imbalanced).

The distribution of weight about each of the four axes was expressed by a balance index which was calculated using the formula (100 − [|side 1 − side 2|])/100, where side 1 is the percentage of the total area occupied by the shapes on one side of a given axis. For example, if the distribution of weight to the left and right of the vertical axis of a design is 40% versus 60%, the balance index for this design would be (100 − [|40 − 60|])/100 or 0.80. Index values range from 1 to 0, where 1 reflects an equal distribution of elements about an axis (e.g., exactly 50% of the black area associated with the shapes above and 50% below the horizontal axis). An index of 0 indicates that all of the shapes fall on one side of an axis.

An average balance index value was computed for each of the six balance ratings as a function of element type and axis orientation. Informal analyses of these means revealed them to be highly similar at each level of perceived balance across all levels of the two factors and so the data were collapsed to provide a single balance index for each of the six balance ratings. These values are presented in Table 4, along with the percentage of the 378 designs assigned each rating.

The principal conclusion to be drawn informally from these data is that the raters were able to perceive relatively subtle differences in the distribution of physical weight about the axes of balanced compositions. Specifically, the average index values obtained for highly, moderately, and somewhat balanced compositions correspond to distributions of 52.5% versus 47.5%, 54.7% versus 45.3%, and 56.2% versus 43.8% of the areas covered by shapes on either side of an axis, respectively. These findings suggest that the mechanism responsible for balance detection is highly sensitive to small differences in the distribution of physical weight about an axis when a design is balanced. They support theoretical assertions that dynamic balance is a very salient perceptual feature of visual displays.

Table 4
Average balance index values as a function of perceived balance rating

Perceived balance ratings	Average balance index	Percent of all compositions rated
6 = highly balanced	0.950 (0.032)	1.1
5 = moderately balanced	0.906 (0.048)	32.2
4 = somewhat balanced	0.876 (0.098)	31.9
3 = somewhat imbalanced	0.748 (0.126)	23.1
2 = moderately imbalanced	0.618 (0.182)	7.4
1 = highly imbalanced	0.324 (0.096)	1.1

Note: Standard deviations are in parentheses.

Balance index data also indicate that the perception of differences in degree of imbalance required greater variation in physical weight about an axis. The average index values obtained for highly, moderately, and somewhat imbalanced compositions correspond to distributions of 83.8% versus 16.2%; 69.1% versus 30.9%, and 62.6% versus 37.4%, respectively.

4. Summary and discussion

The purpose of this research was to examine the extent to which balance serves as an organizing principle underlying adults' compositional strategies for creating visual displays. For each design, we determined the location of its balancing center, the distribution of physical weight about its axes, and the alignment and directional qualities of its compositional elements; three structural characteristics theorized to be primary contributors to pictorial balance (e.g., Arnheim, 1974, 1988; Freimuth and Wapner, 1979).

It was found that the balancing centers of participants' designs were closely aligned with the physical center of the square pictorial field from the beginning to the end of their construction (see Figs. 3 and 4). This was the case regardless of the type of compositional element employed, and despite the fact that the global organization of participants' designs exhibited considerable individuality. These findings support the assertion made by many art theorists (e.g., Arnheim, 1988; Bouleau, 1980; Taylor, 1964) that the location of the balancing center of a square field is primarily determined by the crossing of its four principal axes. Clearly the physical center of the square field functioned as a powerful anchor point about which participants organized a design's structural skeleton.

Another reason to expect that the balancing center would fall in the middle of the pictorial field derives from an optically based explanation of compositional balance in art (see, e.g., Bearden and Holty, 1969). According to this approach, the artist and viewer of a painting usually concentrate on the entire work from the central point of any pictorial field regardless of its shape. From a visual/perceptual point of view, this is because only objects in central vision can be identified in discernable detail. Pattern acuity drops by 50% for an object located only 1° from the center of the fovea, and for an object 8° from center it is only 15% of maximum (Riggs, 1965).

It is for this reason, some argue, that pictorial features conveying important semantic information in Western representational paintings are arranged around the center of a composition as opposed to being found in peripheral areas. Empirical support for this assertion is provided by Locher et al. (1996) who recorded participants' eye movements as they scanned 20th-century paintings. The researchers observed that participants concentrated their gaze in the central region of the paintings; outer regions of the compositions drew very little or no attention.

The ordering strategy used by participants to arrange elements about the center of the pictorial field was found in the present study to be a function of the unique directional qualities of the four compositional elements. Balance was the organizing principle favored by almost all participants for the creation of circle designs. As seen in Fig. 6, structural weight was uniformly distributed about the axes of most circle designs throughout their construction. Because circles are symmetric under rotation and therefore do not possess an orientation, shape directionality can play no part in one's strategy to unify elements into a cohesive whole.

On the other hand, the "linear" quality of squares and rectangles provides strong real and virtual compositional lines, especially within the confines of a square frame. Thus, it is not surprising that participants' primary compositional strategy was to align these elements along an imaginary horizontal–vertical structural grid. For approximately half of the subjects, this alignment strategy was combined with one that simultaneously imposed a relatively balanced distribution of structural weight about the axes of square and rectangle designs (see Fig. 6). Participants did not use opposition of structural weight about design axes, nor alignment within a horizontal–vertical grid as the compositional strategy to construct their leaf designs (see Fig. 6). Rather it appears that they manipulated directionality of the leaves to create an organized global design within the pictorial field. This assertion is based on the finding that the entropy of leaf designs decreased during the initial stages of their construction (see Table 4).

The fact that the choice of the strategy used by participants to organize a composition about the center of the pictorial field was influenced by the structural characteristics of its component shapes is not surprising. Research has consistently shown that the global organizational framework and local distinctive features of compositional elements affect both shape perception and their direction of pointing, important structural determinants of pictorial balance (e.g., Davi and Proffitt, 1993). Thus, a true test of the contribution of the directional qualities of elements to the compositional process resulting in balance must await the results of future research in which participants create displays from a variety of shapes with maximal orientation potentials. Use of such elements will make it possible to investigate systematically the relationship between the overall dynamic quality of designs and oppositional balance. Furthermore, characteristics of the display field such as its shape and the frame that surrounds it are known to influence the perceived structural organization of elements within a field (see, e.g., Herbener et al., 1979) and the influence of these factors on balance should be examined.

An additional factor which must be addressed in future studies if a comprehensive understanding of compositional balance is to be achieved is participant expertise in the visual arts. Locher et al. (1996) have shown that design and museum professionals were in good agreement with untrained individuals as to the perceived structural framework underlying the balance organization of paintings. Research by Locher and Nagy (1996) demonstrated that both art-trained and untrained persons could discriminate between more- and less-balanced versions of paintings following a single brief (100 ms) glance at each. Findings such as these suggest that participant expertise is a factor that need not be considered in balance research.

On the other hand, an eye-movement study of balance perception conducted by Nodine et al. (1993) revealed that art-trained individuals explored balanced paintings differently than did unsophisticated individuals. The scanning patterns of sophisticated individuals indicated that they were more sensitive to the structural organization of a balanced design than were the untrained participants. This research suggests that expertise in the visual arts may indeed influence one's use of balance as an organizing design principle when creating visual displays. The present findings are based on compositions created by novice design students who have not received formal training in the use of balance to construct visual displays. They cannot, however, be considered completely naive with respect to design experience. Therefore, the generality of the present findings must be established by research in which the compositional strategies of adults untrained in any of the visual arts are examined.

Finally, the observation that individuals were able to perceive relatively subtle differences measured quantitatively in the distribution of physical weight about the axes of balanced compositions provides evidence of the visual salience of balance. This finding lends credence to the view derived from tachistoscopic studies of balance perception that viewers can effortlessly discern the extent to which the structural framework of a visual display is balanced. For example, Locher and Nagy (1996) have shown that art-trained as well as untrained individuals could discriminate between more and less balanced versions of the same painting following a 100-ms glance at each. No quantitative measure of the difference in oppositional balance between the two versions of their art stimuli was provided, however.

In conclusion, the ability to quantify the structural organization of visual displays using computer systems like the one employed in this research makes possible a level of experimental sophistication heretofore unavailable to the scientific study of compositional strategies in general and balance in particular. Theories of balance found in philosophical writings can now be subjected to close empirical scrutiny. They receive some preliminary support from the results of this study.

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