Measuring pictorial balance perception at first glance using Japanese calligraphy

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Abstract. According to art theory, pictorial balance acts to unify picture elements into a cohesive composition. For asymmetrical compositions, balancing elements is thought to be similar to balancing mechanical weights in a framework of symmetry axes. Assessment of preference for balance (APB), based on the symmetry-axes framework suggested in Arnheim R, 1974 *Art and Visual Perception: A Psychology of the Creative Eye* (Berkeley, CA: University of California Press), successfully matched subject balance ratings of images of geometrical shapes over unlimited viewing time. We now examine pictorial balance perception of Japanese calligraphy during first fixation, isolated from later cognitive processes, comparing APB measures with results from balance-rating and comparison tasks. Results show high between-task correlation, but low correlation with APB. We repeated the rating task, expanding the image set to include five rotations of each image, comparing balance perception of artist and novice participant groups. Rotation has no effect on APB balance computation but dramatically affects balance rating, especially for art experts. We analyze the variety of rotation effects and suggest that, rather than depending on element size and position relative to symmetry axes, first fixation balance processing derives from global processes such as grouping of lines and shapes, object recognition, preference for horizontal and vertical elements, closure, and completion, enhanced by vertical symmetry.

Keywords: pictorial balance, balance perception, symmetry, Japanese calligraphy, art and perception, art and science.

1 Introduction

> To paint is not to copy the object slavishly; it is to grasp a harmony among many relationships.
>
> Paul Cezanne

1.1 Balance creates unity in art and visual perception

Unity is a primary aesthetic principle throughout art history integrating picture elements into a cogent, articulate expression. It is also the infrastructure of visual organization, as described by Gestalt principles of visual perception. Unity is constructed by grouping or sequencing visual elements or events and attending them. In turn, attention is controlled by balanced relationships among pictorial elements, whereby dominant elements influence meaning and visual value of others. Balance is the sum of relationships among element values, which include: size, color intensity, dissimilarity, and spatial location (Bouleau 1963; Feldman 1981). Balance in paintings is detected rapidly and effortlessly (Locher and Nagy 1996; McManus et al 1985), influencing observer fixation scan path (Locher 1996; Nodine et al 1993).

Balance in art is thought of as the visual equivalent to the work of a gravitational field, borrowing terms such as weight, stress, tension, force, and stability. It was believed that balance can be measured for all finite visual forms, since each has a center around which balance is the resolution of structural relationships. Balance was thought to be largely a

matter of reconciling stresses and weights (Arnheim 1974, 1981). However, as we show here, balance estimation may be more complex, including effects due to observers' past experience.

1.2 Balance and symmetry

Reflection symmetry is the simplest type of balance, in which elements in each half of an image may be complex or locally random, but are recognized globally as echoes or mirror images of each other. Symmetry is detected instantaneously and with minimal effort, especially when about the vertical axis (Barlow and Reeves 1979; Carmody et al 1977; Julesz 1970; McManus 2002; Poore 1976; Wagemans 1995, 1997; Wenderoth 1994, 1995).

Balance, however, is not equal to symmetry, and renowned works of art are constructed with asymmetrical (ie, complex or dynamic) balance (Puffer 1903). Asymmetrical balance is achieved by structural properties working like mechanical weights with a fulcrum at the picture's center, on which an imaginary lever is poised, so that heavy weights can be counterbalanced by lighter ones located further from the center. A "cross-shaped framework" of levers was suggested, set on the vertical, horizontal, and diagonal axes, though the vertical is by far the most salient (see above; also Berlyne 1969, 1971, 1974; Hubbell 1940; Lund and Anastasi 1928; McManus 1980). All axes intersect at the central position, and when their forces are balanced the central position is at rest (Arnheim 1981; Poore 1976).

Multiple properties determine visual weight, including: size (Berlyne 1966, 1971, 1974; Pierce 1894; Puffer 1903), color (Arnheim 1974; Bullough 1907; Pinkerton and Humphrey 1974), and perhaps coarse texture, contrast, and interest. Strangely, there can be an asymmetry between left and right of the vertical axis. Paintings and drawings are perceived differently when viewed in mirror image; left and right have different roles in expressing action, motion, or power (Chatterjee 2002), and the left half of visual space may attract more attention, due to right parietal lobe specialization in attention and emotion (McManus 2002). Similarly, using the ecological view that in natural scenes visual field bottom is generally more crowded, it was suggested that weight at the top should be perceived as "heavier" than at the bottom (Arnheim 1974, 1981).

1.3 Recent studies of balance assessment in art

It is difficult to use works of art for balance perception experiments since they naturally bear ecological validity and are hard to control experimentally. Pictures normally contain the variety of properties mentioned above, but these may be inseparable and perceived categorically. The meanings attributed to pictorial elements ultimately affect our preferences and even our judgments of balance. Nevertheless, we review here studies that have had great influence on current understandings of balance perception.

Balance judgment is the same for colored and black-and-white reproductions of art works. Spatial location seems more prominent in balance judgment than color or size; and, counter to Arnheim's ecological theory, studies show that vertical position does not affect balance, despite the illusory effect of perspective (McManus et al 1985). Furthermore, cropping the left or right edge of the picture moves the perceived center of balance towards the new middle regardless of specific objects, suggesting that balance results from global integration of information (McManus et al 1985). Recent results show that when subjects are asked to crop photographs the resulting center of mass is close to the original symmetry axis framework (McManus et al 2011).

Various investigations linked balance to composition "correctness", "rightness", or "goodness", comparing original compositions with perturbed versions, producing theories based on aesthetic experience and viewers' art expertise (Locher 1996, 2003; Locher and Stappers 2002; Locher et al 1998, 1999, 2005, 2007; McManus and Kitson 1995; Nodine et al 1993). The directionality of elements and their implicit dynamic quality contribute to their weight and

composition balance (Locher and Stappers 2002; Locher et al 1998; Mead and McLaughlin 1992). Studies suggest that both art-trained and novice viewers rapidly achieve complex global impressions of artwork gist including balance perception (Locher and Stappers 2002; Locher et al 1996, 2007; McManus et al 1985), perhaps within 100 ms, though these studies did not employ methods to isolate early processing from later cognitive processing. Yet, eye movements suggest that gist perception for the first 3 s derives from a subset of elements concentrated in a limited area (∼ 25%) around image center, with the rest of the image remaining unattended (Locher 1996; Locher et al 2007). Scan paths for artist and novice viewers diverge at longer processing times (Nodine et al 1993; Zangemeister et al 1995), when expert aesthetic judgments are influenced by composition balance (Locher et al 1996, 1999; Nodine et al 1993).

1.4 Models of balance computation

Two recent balance computation models are the "visual aesthetic sensitivity test" (VAST) and the "assessment of preference for balance" (APB) test. The VAST stimulus set consisted of 42 pairs of black-and-white abstract images. VAST measured aesthetic taste judgments by eight artists (following lengthy viewing times) and determined, in the context of general aesthetic preference, a balance sensitivity scale by the level of agreement of a random group of viewers (Götz et al 1979). Further results showed no difference between cultures, ages, or art expertise (Eysenck 1983; Iwawaki et al 1979). Since VAST is based on subjective judgments of a fixed set of images, it cannot be transferred to novel images.

The APB test (Wilson and Chatterjee 2005), on the other hand, is based on the cross-shaped framework of levers on the vertical, horizontal, and two diagonal axes, with a fulcrum at their central intersection (see above; Arnheim 1974). Balance scores are expressed as the sum of area balance ratios across the eight symmetry axes (see Equation 1). APB was tested using square framed images with a white background and compositions of scattered black geometrical shapes (squares, circles, or hexagons) of varying size and location and extended viewing. APB scores matched subjective balance preferences and evaluation results well and successfully addressed several weight factors in complex balance—accounting for a variety of shapes, sizes, and compositions. However, APB isolates these factors from other pictorial factors that grant art ecological validity. The use of black geometrical shapes was based on the conjecture that balance preference is "form preference" isolated from "content preference" since the latter is culture dependent and balance perception is similar across cultures (Chatterjee 2002, 2004; regarding VAST test, above, see Götz et al 1979).

1.5 The current experiments

The above studies generally focused on long duration processing (greater than a few seconds), allowing free eye movements and influences of later cognitive processes (even when using short displays). We now address the case of very brief and masked presentation. What is the nature of balance computation, and what picture elements or features are selected for balance processing during first fixation? After all, perhaps even during first fixation covert attentional shifts provide extrafoveal information related to image elements, spatial layout, and scene structure (Awh et al 2006; Horowitz et al 2007; Posner 1980; Wolfe 1994). In addition, we ask if balance processing is influenced by art expertise even at first gist.

We compare results of two tasks—balance rating and direct balance comparison—using brief displays followed by a backward mask (see Methods) and compare results with APB scores. In addition, we specifically inspect whether vertical mirror symmetry plays a special role in balance perception (Machilsen et al 2009). We repeat the rating task, rotating the images by ±45, 90, and 180°, which does not change their APB balance score but may change their global appearance and affect grouping and holistic shapes. Finally, we examine the role of expertise in balance processing during first fixation in isolation from later

cognitive processes. On the basis of the results of these three experiments, their apparent disagreement with APB model predictions, and comparison with previous findings, we suggest principles for balance perception and computation beyond weights and axes, making specific suggestions as to what element features contribute to balance perception.

In these studies we use Japanese calligraphy images as stimuli. Japanese calligraphy is pictorial art (so, admittedly, not completely controllable) and at the same time is limited to black-on-white images—fit for the cross-shaped framework and enabling conditions similar to those used for geometrical shapes in the APB computation study. Moreover, a main aesthetic principle in Japanese calligraphy is balance along a central vertical axis. Finally, the predetermined position of a character within a fixed frame appears in Japanese calligraphy instruction guides, in order to teach the fine balance within each character, as demonstrated in Figure 1 (Karita 2006). Thus, these calligraphy images are ideally suited for our study of balance perception.

Figure 1. Ancient calligraphy carved in stone in square frames (left); ink imprints of such characters from stones, used for copying and practice (center), and such imprints and their enlargements from a modern calligraphy instruction guide (right). Note the thin vertical line marking the balance center within and between characters (right; from Karita 2006).

2 Rating and comparison experiments

2.1 Methods

2.1.1 *Participants*. Participants in Experiments 1 and 2 were 30 university students aged 23–28 with normal or corrected-to-normal vision, no art training, and no familiarity with Japanese characters (the *novice* group). Stimuli were presented in a darkened room on a 19-inch monitor, 1024 × 768 pixels. Participants' heads were fixed using a supporting frame, at a viewing distance of 60 cm. Images were ~ 7° in diameter, at screen center or ±10° lateral. Masks covered the entire screen.

Prior to the experiment participants were shown a pair of calligraphy images, one extremely balanced and one extremely unbalanced. They were asked to point to the more balanced and explain their considerations for balance evaluation. Several reported that this was related to symmetry; a few pointed to the vertical and/or horizontal symmetry

axis. Others reported that various image features were important: high density, geometric components, and closed shapes. None reported that they knew about complex balance in pictures. Experiments were in accordance with the World Medical Association Helsinki Declaration as revised in October 2008.
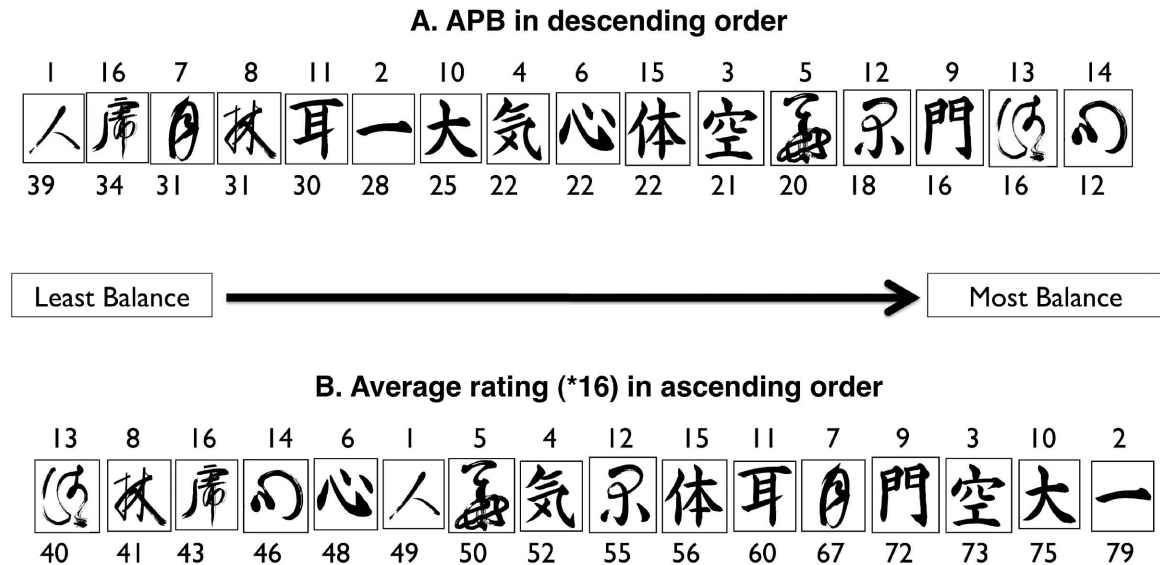
A. APB in descending order

B. Average rating (*16) in ascending order

Figure 2. Japanese calligraphic characters used as stimuli for Experiments 1 and 2 arranged from left to right according to (a) their APB balance scores (see Section 2.1.3) and (b) average participant rating (multiplied by 16; see Section 2.2.2). Above each image is its image number. Note that high APB scores reflect low balance, and vice versa. (APB scores and average ratings are rounded off to the nearest integer.)

2.1.2 *Stimulus images.* The 16 images of Japanese calligraphy shown in Figure 2 were used as stimuli. They are characters (kanji) taken from a collection of famous historical artworks (Addis 2006), calligraphy instruction guides, and a calligraphy dictionary (Earnshaw 1989, Karita 2006, Takada 1992). The selected images represent the three styles of Japanese calligraphy; (image numbers appear above the images in Figure 2):

(1) block script (*kaisho*), images 2, 3, 4, 6, 9, 10, 11, 15;
(2) semicursive script (*gyosho*), images 1, 8, 12, 16;
(3) cursive script (*sosho),* images 5, 7, 13, 14.

The images include a variety of configurations, element number, and complexity of shape. Each image was set in a 400 × 400 pixels square, 20–28 pixels from the two sides for the larger of the vertical or horizontal dimensions, based on frame principles used in Japanese calligraphy instruction guides (Earnshaw 1989; Karita 2006).

2.1.3 *APB balance scores.* APB balance scores (Wilson and Chatterjee 2005) were calculated using a Matlab program. The image was bisected to area 1 and area 2 on either side of each of its four principle symmetry axes—horizontal (H), vertical (V), main diagonal (MD; bottom left to top right), and antidiagonal (AD; bottom right to top left)—and the balance components were computed as the difference between the areas as a percent of their sum (Figure 3, left). That is,

$$\text{APB balance ratio} = \sum \frac{|(\text{area 1} - \text{area 2})|}{|(\text{area 1} + \text{area 2})|} \times 100. \tag{1}$$

Using the same equation, four "in-out" balance components were computed: for each principle axis the image area was bisected to its inner and outer halves (as demonstrated for the vertical axis; Figure 3, right).
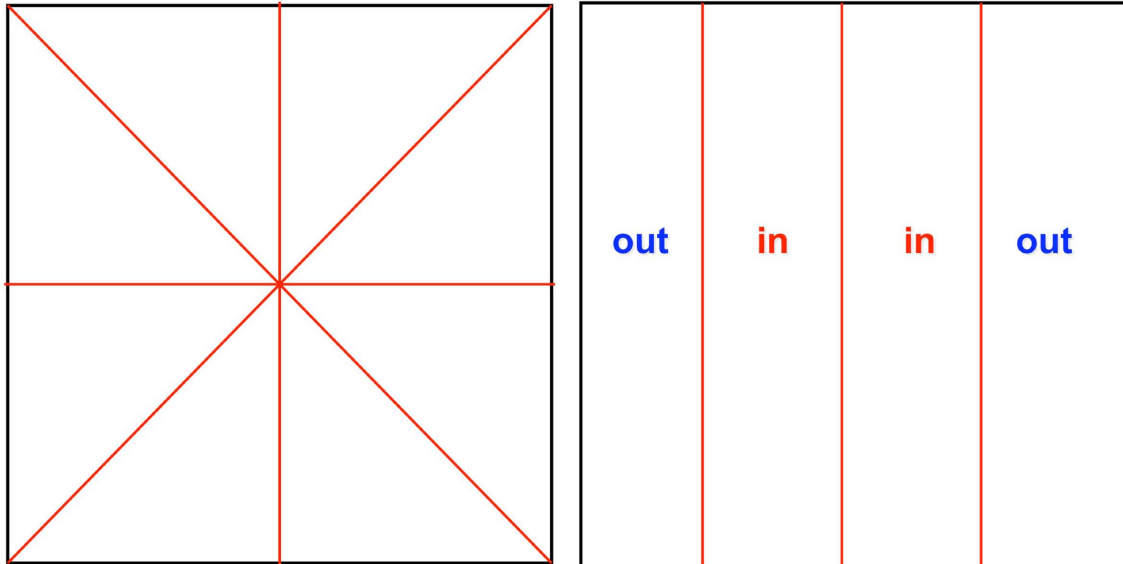

Figure 3. Four principle symmetry axes for image bisection (left); illustration of in-out bisection for the vertical axis (right).

Balance scores were absolute values, ignoring possible impact of extra pixel count on a particular side of the axis (such as up versus down or left versus right). Computed APB balance scores for the eight symmetry axes of each image and total balance scores are summarized in Table 1.

Image APB balance scores range between 11.6% and 39.1% as shown in Figure 2a. Note that, since APB scores are based on differences in weight between two sides of a symmetry axis, lower scores correspond to smaller differences, hence to *more* balance, and larger scores to less balance. Thus, according to APB, image 14 with a score of 11.6 should be the most balanced and image 1 with a score of 39.1 should be the least balanced (Figure 2a). APB imbalance (high scores) may derive from any of the eight independent measures. For example, many images receive high imbalance scores due to greater weight in their central than in their outer regions (ie, high in-out components).

2.1.4 *Experiment 1: balance rating*. The first experiment measured novice participant balance ratings during a single fixation for the 16 images and their mirror images, in three spatial locations—left, center, and right of visual field center. Trial image sequence was generated in pseudorandom order counterbalanced among subjects. Subjects completed 96 trials in a sequence. Results allow us to rank stimulus images by rated balance. We repeated this test following completion of Experiment 2 to determine learning effects. Results were almost identical.

Participants started each trial by fixating the cross mark at the center of the screen and pressing the space bar. Then a stimulus character or its mirror image was presented for 200 ms at left, center, or right of the computer screen. This was followed, after an interstimulus interval (ISI) of 250 ms, by a 500 ms mask covering the entire screen, which served to isolate responses from later cognitive processing. Finally, a response screen was presented, on which

Image	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Main Axes																
H	15.2	14.3	2.1	3.1	38.2	18.8	8.4	15.8	33.5	4.3	25.5	4.9	23.5	3.3	4.5	23.5
V	28.4	14.3	13.8	14.5	7.4	14.4	11	1.4	8.2	13.8	7.2	13.3	21.6	7.4	13.3	24.1
MD	33.8	19.4	18.2	8.5	5	6.1	18.7	24	20.5	23.9	20.6	16.5	11.3	4	2.6	25.4
AD	40.3	8.2	11.7	7.3	27.8	11.4	1.8	21.5	31.8	5.2	35	7.1	1.7	16.6	3.4	29.4
In-Out Axes																
H	55.7	100	28.5	20.7	4.6	69.7	34.3	46.3	14.1	25.7	16	5.4	2.2	44.6	54.7	31
V	51.1	7.5	49.1	55.1	52.4	4.1	98.1	51.1	2.5	51.5	65.8	50.9	42.2	2.6	40.6	69.6
MD	32.6	16.8	21.5	48.7	22.1	42.3	25	43	19.2	53.2	32.7	24.1	15.4	8.5	32.7	11.6
AD	55.4	47	24.7	19.7	3.7	9.8	51.5	43.1	1.5	25.3	33.6	17.9	8.9	6.1	20.3	58.9
Total Score	**39.1**	**28.4**	**21.2**	**22.2**	**20.2**	**22.1**	**31.1**	**30.8**	**16.4**	**25.4**	**29.5**	**17.5**	**15.9**	**11.6**	**21.5**	**34.2**
Rating	3.1	5.0	4.6	3.2	3.1	3.0	4.2	2.6	4.5	4.7	3.7	3.4	2.5	2.9	3.5	2.7
S.D.	1.5	1.2	1.1	1.3	1.3	1.3	1.3	1.2	1.2	1.3	1.2	1.3	1.1	1.1	1.3	1.5
Rating*16	49.4	79.5	72.9	51.6	50.0	47.6	66.8	41.1	72.0	74.8	59.9	54.9	40.4	45.7	56.4	42.7

Table 1. APB computed balance for main and in-out axes and total score. H = horizontal; V = vertical; MD = main diagonal; AD = antidiagonal.

participants rated the character for balance on a scale of 1 (least) to 6 (most). Figure 4 displays this trial sequence.
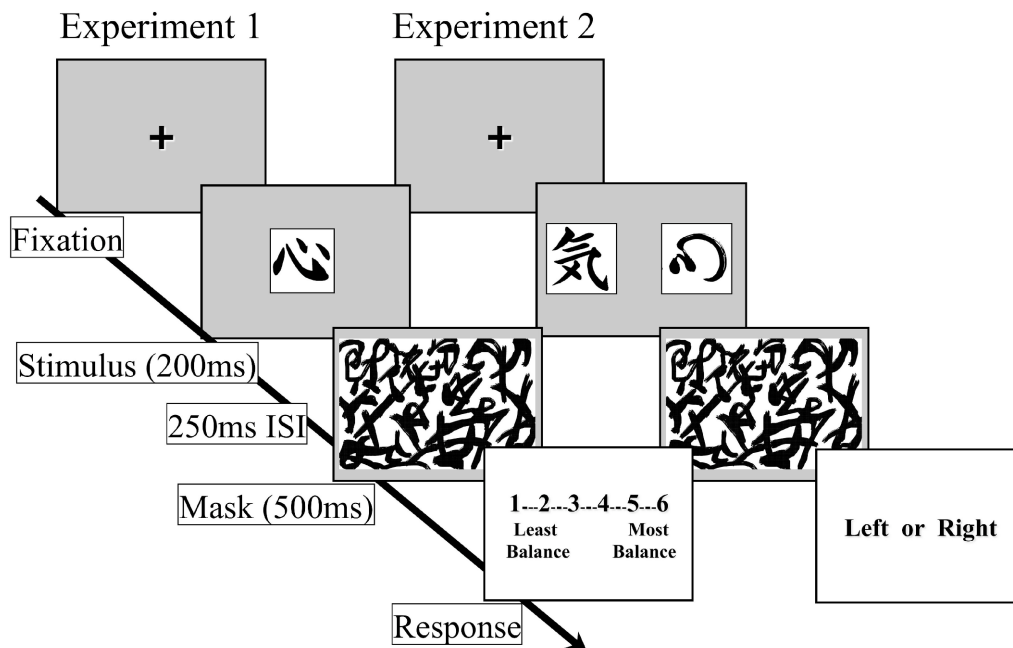

Figure 4. Experiment 1: procedure for balance rating. On each trial an image (or its mirror image) was presented in one of three positions: left, right, or center (shown). Experiment 2: procedure for balance comparison between images (presented simultaneously at left and right of center).

2.1.5 *Experiment 2: balance comparison.* This experiment used a two-alternative forced choice (2-AFC) paradigm with two images presented simultaneously, left and right of fixation. Each of the 16 images was compared with each of the others, with itself, and with its vertical mirror image (in right vs. left placement or vice versa). Trial image sequence was in pseudorandom, counterbalanced order. Each subject completed 288 trials. Procedure was

similar to that of Experiment 1. Presented with a response screen, participants chose the more balanced image (Figure 4).

2.2 Results

2.2.1 *Experiment 1: balance ratings.* For each of the 16 images balance ratings were averaged across the 30 participants. Figures 5a–c show correlations between balance ratings for images and their mirror images in each of the three display locations: left (a), center (b), and right (c), with slopes of 0.95, 1.05, and 0.98, and $R^2 = 0.96, 0.96$, and 0.97, respectively. The near-unity slopes and very high correlations reveal that differences in image appearance due to mirror reflection did not significantly affect balance rating, suggesting that during first fixation perceived imbalance is independent of the side of the vertical axis where excess weight is found and of the implied dynamic and directionality. Moreover, the similarity of the three rating graphs reveals that image spatial location in the visual field has no significant effect. Rapid balance perception occurs at fixation and in peripheral vision.
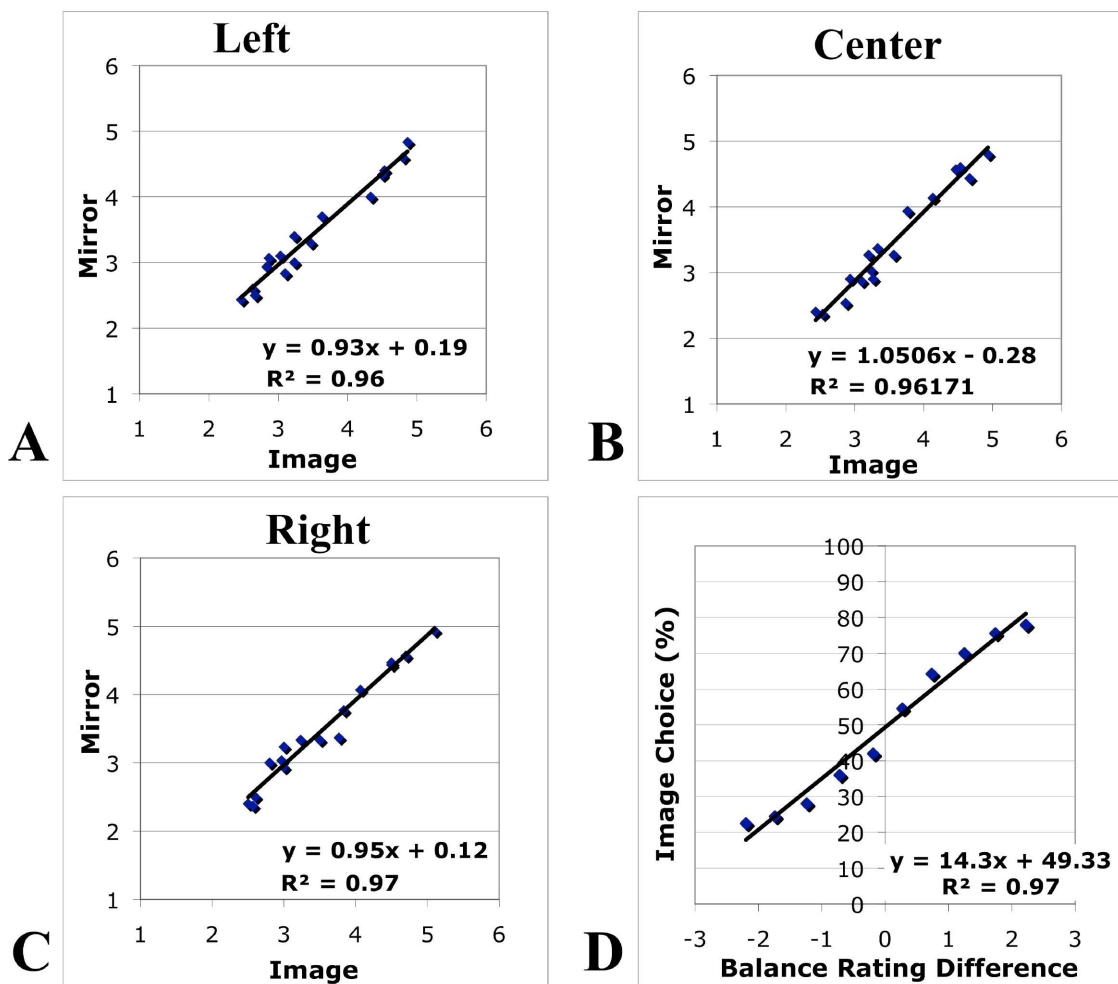

Figure 5. Correlations between balance ratings for the 16 images and their vertical mirror-reversal versions in the three display locations: (a) left; (b) center; (c) right. (d) Correlation between results for balance rating (Experiment 1) and two-alternative forced choice balance comparison (Experiment 2).

2.2.2 *Experiment 2: Comparing balance of two images.* Each image could appear on the right or left of the screen in the comparison tests, yielding two measures of its mean balance preference compared with each of the other images. Some images were chosen as "more balanced" in as few as 30% of the cases, while others in as many as 70%. This limited range

reflects intrasubject and intersubject variability. To confirm the above result that balance preference is independent of spatial location, we compared preference of each image when on the left with when on the right. There were no differences; the results are highly correlated ($R^2 = 0.95$).

The rating results of Experiment 1 and comparison results of Experiment 2 are confirmed by their being correlated with each other. Figure 5d demonstrates the probability of choosing an image (in Experiment 2) as more balanced than a particular comparison image, as a function of the difference in the participant's ratings of balance for these two images (in Experiment 1), averaging results over images with similar ratings. There is striking correlation between these experimental results ($R^2 = 0.97$).

However, no correlation was found between viewers' balance ratings and APB balance scores ($R^2 = 0.0005$), as seen in Figures 2 and 6. Note that since the rating range was 1–6 and the APB balance score range was 1–100 we multiplied ratings by 16 for comparison with APB. Since results of Experiments 1 and 2 are highly correlated, as seen in Figure 5d, we do not demonstrate directly the lack of correlation of Experiment 2 with the APB results.
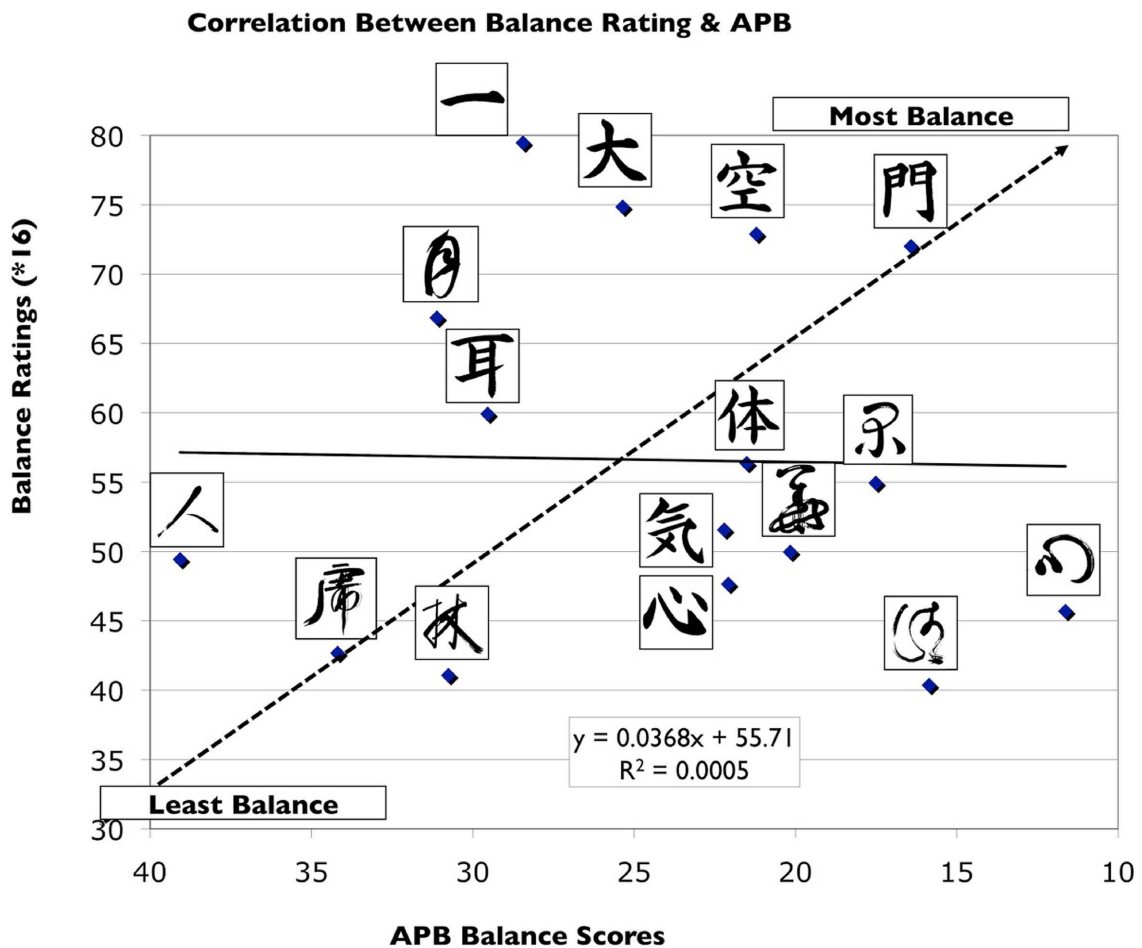

Figure 6. Correlation between the APB balance scores and the balance rating results; (dashed diagonal line represents full correlation; black line represents actual results).

We further examined correlations between rating results and APB scores of each symmetry axis, in order to investigate the possibility that the APB score for one or several symmetry axes might predict ratings. None of the separate axis APB scores was significantly correlated with subject ratings, as summarized in Table 2 (the highest R^2 was 0.05 for the diagonal axis).

Similarly, we computed correlations between APB and individual subject rating results to see if APB predicts balance ratings of some participants. However, such a subgroup was not found (correlation range was between 0 and 0.27, with only 4 out of 30 subject ratings showing a correlation above 0.1).

Table 2. Correlation (R^2) between individual symmetry axis APB and balance ratings.

Symmetry axis	Main axis	In-out axis
Horizontal	0.036	0.037
Vertical	0.024	0.007
Diagonal	0.050	0.003
Antidiagonal	0.037	0.005

2.3 Discussion

In two psychophysical experiments we examined novice subject balance ratings for first fixation of single images—displayed left, center, or right of fixation—and balance comparison of two images in left and right positions. Both balance results separately, as well as their correlation, show consistency in novice subject balance ratings during first fixation of calligraphic images over various viewing conditions and tasks. This suggests that balance is a defined and important feature of image processing already in early visual perception, prior to eye movements and influences of later cognitive processes, and that as early as first fixation there is a specific perceptual computation of balance. This finding is consistent with—and extends—the results and conclusions of earlier studies (Arnheim 1974; Götz et al 1979; Locher et al 1996; McManus and Kitson 1995; McManus et al 1985; Nodine and Krupinsky 2003; see Introduction). Furthermore, we find balance perception to be independent of image position in the visual field. Our results also show consistently that an image and its (vertical) mirror reflection are perceived equally balanced, so that, unlike suggestions by earlier studies (eg, Locher and Stappers 2002; see Introduction), element directionality, at least from left to right vs. right to left, is probably not processed at this early visual stage and does not play a role in balance perception at a glance.

Unexpectedly, the APB balance score did not match balance ratings. We shall see in the following section that there is a strong dependence of ratings on image rotation. This, too, is not predicted by APB and also suggests that other computations based on averaging image features, such as center of mass or center of gravity, are probably not effective in predicting balance perception at first glance. In summary, our results suggest that perceived balance is not necessarily a statistical quality of an image, but has other rules or criteria. Nevertheless, although there is a significant difference between the roles of left and right in art, particularly in portrait paintings and themes expressing action and motion (Chatterjee 2002; McManus 2002), there is none in balance perception at a glance—at least for this set of Japanese calligraphy images as correctly predicted by APB.

3 Art trained vs. novice viewer balance rating for rotated images: Experiment 3

3.1 Methods

Two groups participated in this experiment: 10 "novice viewers", university students with no art training, and 13 "artists", art academy students with ≥3 years full-time art training. Other conditions were identical to Experiments 1 and 2.

For each of the 16 original images four additional rotated versions were prepared using Photoshop software, adding to the original image (0° rotation), images rotated by ±45, 90, and 180°. Figure 7 shows examples of image rotation sets for stimuli numbers 1, 8, and 13; (see Figure 10 for additional examples). Note that with rotation there can be a transition
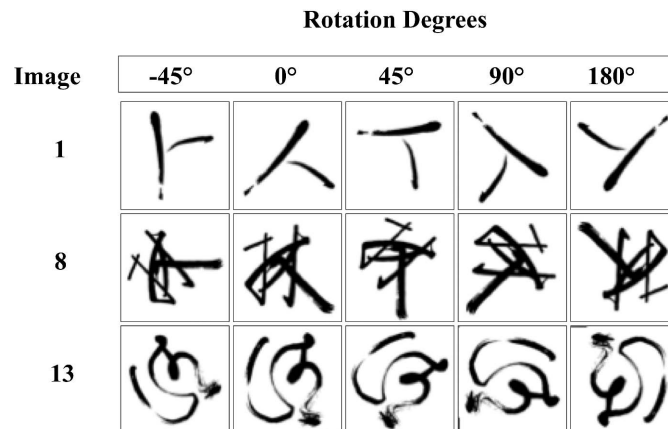
Rotation Degrees					
Image	-45°	0°	45°	90°	180°

Figure 7. Three images (1, 8, and 13) and their four rotated versions.

from horizontal or vertical elements to diagonal ones, and/or vice versa, so that perceived shapes can change with rotation (as in square versus diamond). For example, in image 1 the diagonal elements in the original image (0°) are transformed into a composition of horizontal and vertical elements at $\pm45°$. Furthermore, observers may accept as vertical or horizontal elements which are only approximately so, but do not do the same for diagonal elements. The use of four main axes for APB means that there is no change in computed balance score with these rotations. The question is: will there be differences in participant ratings with rotation?

We repeated the balance-rating task of Experiment 1 (see above, Section 2.1.4, and Figure 4, left) with rotated images, but only at fixation. Stimulus image display was in pseudorandom order, avoiding consecutive display of the same character even at different rotations, spacing them by at least three displays.

3.2 Results

Artist and novice participants had similar tendencies, agreeing on which image in which rotation was more or less balanced. Nevertheless, artist mean responses showed greater rating differences between rotations, as shown in Figure 8. Artist difference between highest and lowest mean rating was 1.1 (4.2 for original image rotation; 3.1 for −45°), and novice difference was 0.5 (3.6 for original; 3.1 for −45°).

A two-way ANOVA showed significant main effects of art expertise and image rotation: expertise, $F(1, 150) = 11.93$, $p < .001$; image rotation, $F(4, 75) = 8.24$, $p < .001$. The main effect of expertise reflects generally lower ratings of novices. The main effect of rotation reflects greater balance perceived for 0° and 180°. Analysis of simple effects showed greater balance rating dependence on rotation for artists; simple main effect of rotation was significant for artists, $F(4, 75) = 8.04$, $p < .001$, but not for novices, $F(4, 75) = 1.59$, $p = .2$.

The differential effect of rotation on expertise is seen in Figure 8. Simple main effects of expertise at rotation was significant for all rotations except −45°: at 0° (original image), $F(1, 251) = 71.39$, $p < .001$; at 45° (vertical/horizontal elements turned clockwise into diagonals), $F(1, 251) = 7.06$, $p < .001$; 90° (vertical/horizontal elements interchanged), $F(1, 251) = 22.62$, $p < .001$; 180° (image flipped on its head), $F(1, 251) = 34.47$, $p < .001$; whereas at −45° (counterclockwise diagonal of the original image) the simple main effect of art training is not significant, $F(1, 251) < 1$, $p = .37$. Note that artist ratings at both 45° and −45° were lower than for other rotations, but not so for novice ratings.

Post hoc t-tests confirmed the differential effect of rotation on balance ratings for each expertise group, as shown in Table 3: for novice participants ratings were significantly different for the original image compared with each of the rotations, but differences between
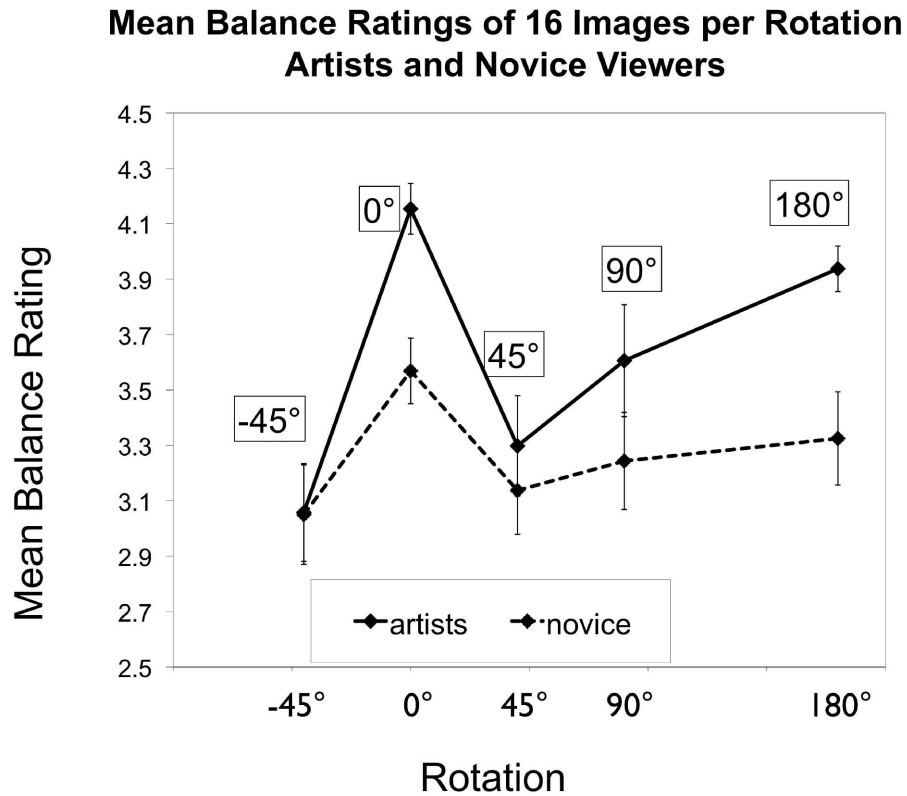
Mean Balance Ratings of 16 Images per Rotation
Artists and Novice Viewers

Figure 8. Balance ratings averaged across the 16 stimuli (artists: solid line; novice viewers: dashed line); error bars are between-image standard error.

any pair of rotations ($\pm 45, 90, 180°$) were not significant. For the artists, on the other hand, ratings were significantly dependent on rotation for most pairs, excluding $0 - 180°$ and $45 - 90°$, and were barely significant for $45°$ to $-45°$. Note that, overall, comparisons for artists are more significant than for novices, except in the one case of comparing $0°$ and $180°$. Perhaps artists give high balance ratings also for the $180°$ rotation for cases where this adds a wide base to the image (as in images 11 and 14 shown in Figure 10; also image 9 shown in Figure 9e, with an increased support ratio).

Table 3. *p*-values for paired *t*-test comparisons between balance ratings by rotation.

Rotations (°)	Novice				Artist			
	45°	90°	180°	−45°	45°	90°	180°	−45°
0	**0.015**	**0.018**	**0.012**	**0.005**	**0.0002**	**0.007**	0.139	**0.001**
45		0.479	0.245	0.483			0.163	**0.009**	**0.049**
180				0.092				**0.0002**
Note: Figures in bold are significant.								

Note also that the APB measure does not predict a dependence on rotation by multiples of $45°$ since it simply adds the balance values for the eight different axes. To understand the balance rating rotation dependence that we do find, we suggest that Japanese calligraphy images often have dominant vertical and/or horizontal elements and these elements change with rotation. Examples are demonstrated in Figure 9. Some images were rated much lower at $\pm 45°$ rotations than at other rotations by both participant groups, as seen, for example, in Figure 9b (image 2), where it is apparent that artist responses were more rotation dependent
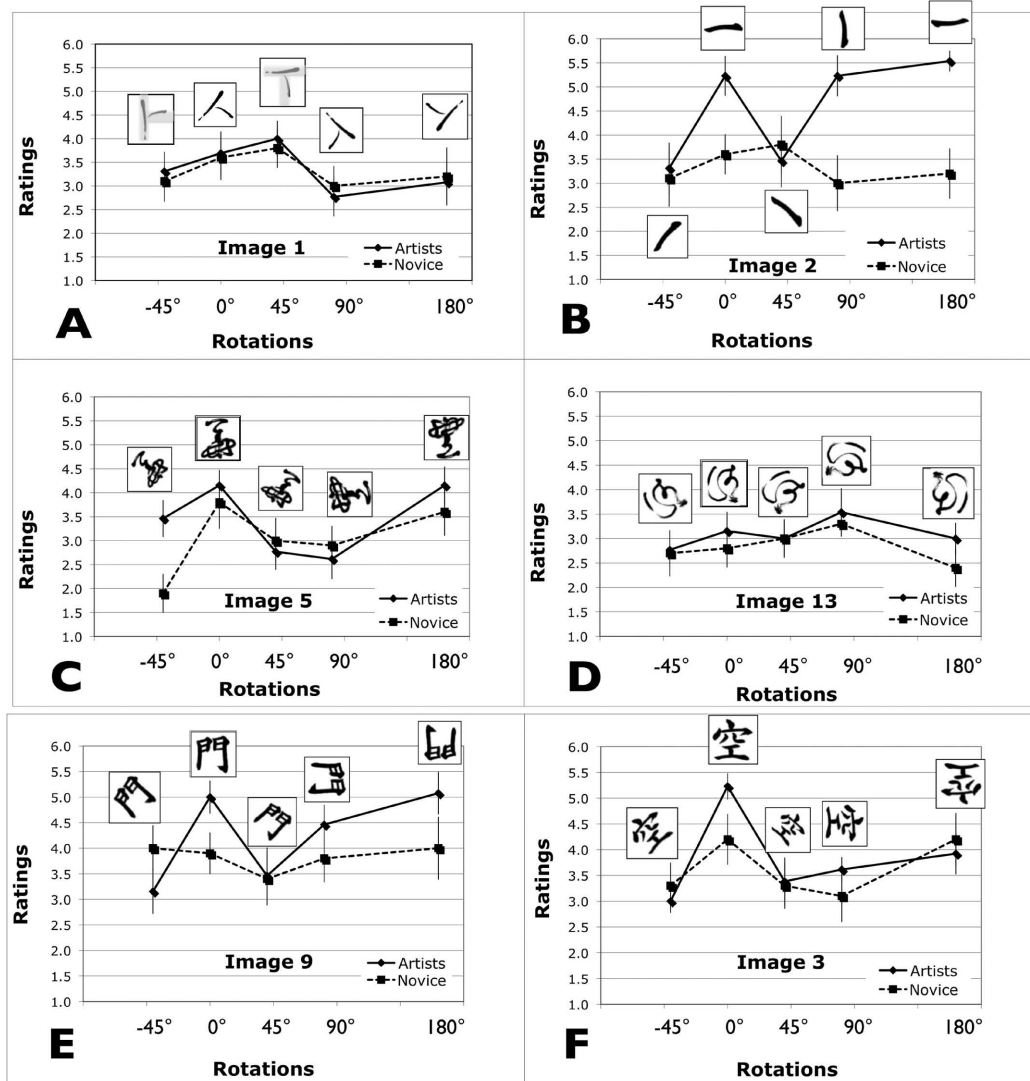
Figure 9. Examples of image balance ratings by artists (bold lines) and novices (dashed lines) for five different rotations. Note that generally the rotation effects seen in the artist ratings are reflected in similar, but reduced, tendencies in novices. A number of rotation effects are demonstrated, as follows: (a) images were generally rated higher at 45° rotation, where diagonal elements become vertical and horizontal creating a T-like shape, especially when the T is upright; (b) images were generally rated lower at ±45° rotation, where horizontal and vertical elements become diagonal; (c) images at ±45° rotation were rated similar to that at 90° rotation, where the image was rated low because vertical and horizontal elements are flipped and vertical symmetry is violated; (d) images with curved lines and no salient vertical or horizontal lines were rated similarly at ±45° rotation as at other rotations; (e) images with a wider base or greater support ratio at 180° rotation than at 0° were rated similar to that at 0°; (f) images losing their wide base at 180° rotation were rated lower than at 0° by artists.

and consistent across participants than those of novice viewers. At ±45° rotations horizontal and vertical elements turn into diagonals, and diagonal elements lend less support to balance.

This conclusion is supported by two cases in which ±45° rotations did not receive the lowest ratings. The first is demonstrated in Figure 9a (image 1; also found for image 8 in Figure 10), where the image received the highest rating at 45° rotation. In these cases the most salient elements of the original image were diagonal, and at 45° rotation these turn into horizontal and vertical, composing a shape similar to the letter "T". In contrast, at −45° rotation the vertical and horizontal elements composed a sideways T, (⊢), and ratings are

still high (but lower than at 45° rotation). The second case is when the original image has vertical symmetry, which is broken at 90° rotation. For these images 45° rotation received similar or higher ratings than 90° rotation where vertical symmetry was lost (while 0° is still rated highest), as seen in Figure 9c (image 5; also images 11 and 12 in Figure 10).

Other cases in which ±45° rotation ratings were not significantly lower that 0° involve images that do not have salient vertical or horizontal elements, or which form round shapes, as demonstrated in Figure 9d (image 13; also images 4 and 14 in Figure 10). As seen in Table 3, the difference between 0° and 180° was significant for the novice group, but not for the artist group (images 2, 5, 7, 9, 12, 13, and 16). Artists rated images at 180° similar to the originals, as demonstrated in Figure 9e (image 9; or higher than originals images, as for images 11 and 14 in Figure 10). In such cases at 180° the image was standing on a broader base, or the base had greater support ratio, such as in image 9 in Figure 9e, as opposed to image 3 in Figure 9f, where it seems that the pointed element at the base decreases perceived balance. In the novice group, however, rotation had only a weak effect on ratings, which may raise the hypothesis that they perceive images more holistically, minding salient elements and overlooking minor ones; artist training—specifically in formalism—may improve rating consistency by interfering with holistic processing.

The summary chart of Figure 10 compares the rotation dependences of artist balance ratings for all image sets, selecting artist ratings since they had greater between-rotation variance and showed better consistency. Note that images occupying the higher rating range of 4.0–5.5 are composed solely or saliently of horizontal and vertical elements, and mostly maintain vertical symmetry. The images occupying the lower balance rating range 2.5–4.0 have either salient diagonal or curved elements, or a violated vertical symmetry. We discuss below specific features that influence perceived balance.

4 General discussion

We examined visual balance perception at first fixation, comparing observer balance ratings of Japanese calligraphy images with their APB balance scores. While within-subject, between-subject, and between-experiment ratings were highly consistent, there was little similarity between these and APB scores. We conclude that while APB is an adequate balance rating method for geometrical shapes (without grouping effects, as tested by Wilson and Chatterjee 2005) this method does not reflect balance assessments of more complex images, such as art.

Our observations suggest that early balance processing takes into account organization of lines and shapes, as well as global grouping effects, enhanced by vertical symmetry, closure, and completion. Balance assessment seems to derive from global processes rather than purely from statistical analysis of element size, direction, and location. This is demonstrated by image rotation as well as between images. Perception of balance already at first fixation shows that art experts have an advantage over novices that is manifested in more staunch balance assessments. It would be useful to investigate further the comparative roles of each of these effects on balance processing.

4.1 Elements of perceived balance

The summary chart of Figure 10 facilitates observation of balance-assessment changes that occur within each image set through rotation as well as across images. We review here the most salient elements that seem to drive balance perception, leaving detailed study of these trends to further systematic study.

- **Horizontal and vertical elements.** The most-balanced sets (upper right in Figure 10) are composed mainly of horizontal and vertical elements. In the less-balanced stimulus sets (lower left in Figure 10) the main feature is a lack of straight lines. This is consistent with the *aesthetics oblique effect*; for example, observers show aesthetic preference
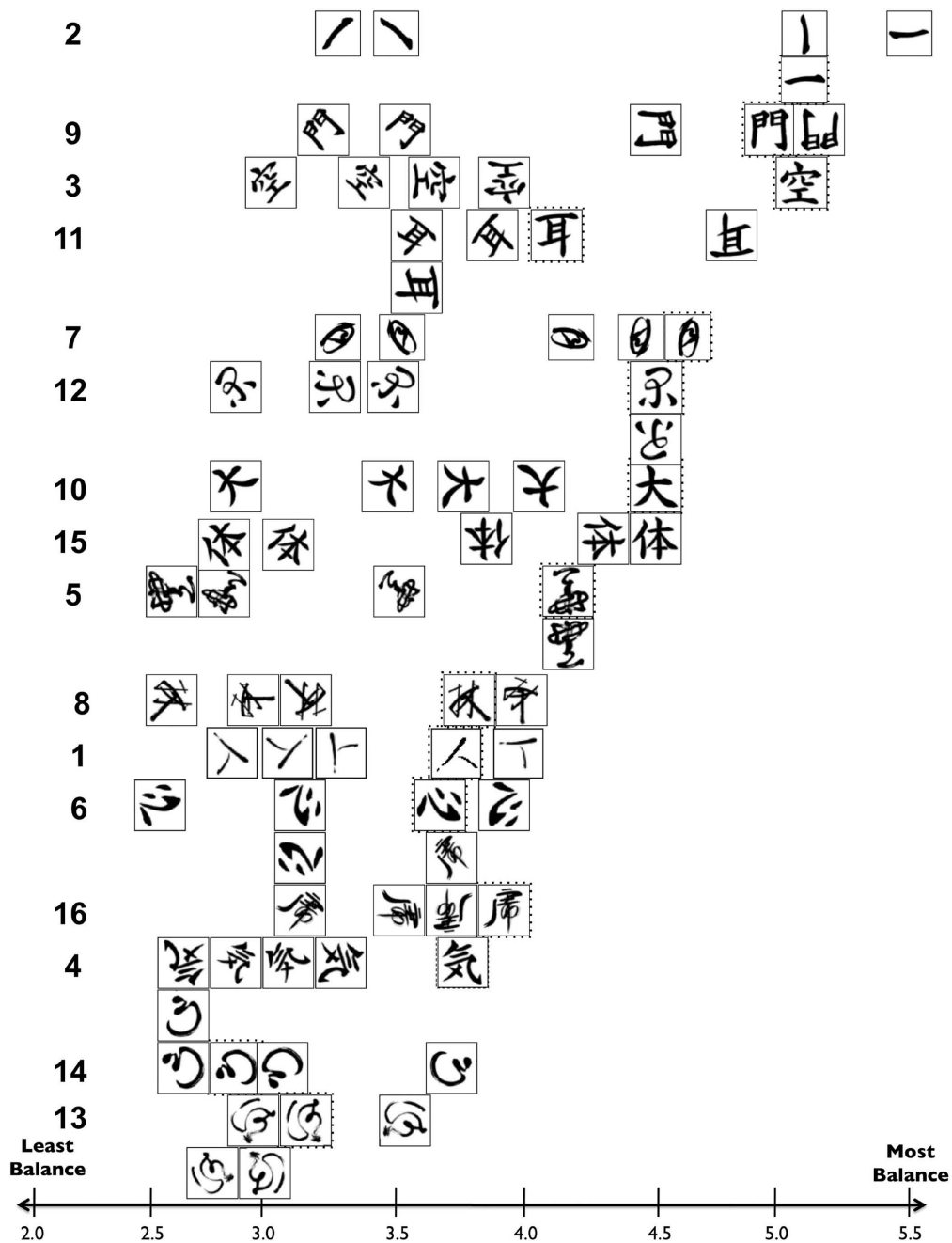
Figure 10. The 16 image sets ordered according to artist group balance ratings—from most balanced (top right) to least balanced (bottom left). Original images (0° rotation) are marked by dashed frames; image numbers are indicated on the left.

for Mondrian paintings oriented with vertical and horizontal elements over rotated versions with oblique elements (Latto and Russel-Duff 2002; Latto et al 2000; Plumhoff and Schirillo 2009).

- **Vertical mirror symmetry.** In the more balanced images vertical symmetry is either maintained or, with grouping of a number of nonvertical elements, even enhanced. With 90° rotation there is a switch from vertical symmetry to horizontal symmetry. As a result, vertical symmetry may be violated and the image is perceived as less balanced. This effect is exacerbated for ±45° rotations, when the symmetry is around the diagonals. These results are consistent with previous studies that found vertical

mirror symmetry salience compared with horizontal or centric mirror symmetry in a variety of object perception tasks and suggested that vertical mirror symmetry is used as a cue for figure–ground segregation and element grouping in a display of Gabor elements (Machilsen et al 2009; Wenderoth 1994, 1995). We now suggest that vertical symmetry is also a critical cue for perceived balance.

- **Imprecision of verticality and horizontality.** According to Japanese calligraphy tradition, all seemingly horizontal lines are in fact either slanted or slightly arched. Yet they are satisfactorily perceived as horizontal. For example, in the very top set of Figure 10 the horizontal lines are curved mostly above or below the horizontal axis, yet are perceived as resting on the horizontal axis. This is in line with Arnheim's (1974) observation that visual experience cannot be described in terms of precise property measurement units. For example, when people see a 93° angle they perceive "an inadequate right angle". Likewise, almost perfectly parallel lines are as likely to be perceived as parallel or as not parallel (Kukkonen et al 1996). Quasi-invariant properties such as near parallelism are influential in object recognition over novel viewpoints and rotations (Wagemans et al 2000), similar to the nonaccidental property of perfect parallelism (Biederman 1987).
- **Grouping and closure.** In many of the balanced sets parallel near-horizontal elements form meaningful shapes, closely resembling squares or rectangles through grouping and closure. These are not real rectangles or even parallelograms, since their angles are not 90° or their lines are not truly straight. Yet, their global percept is as straight, perpendicular, or parallel lines. The less-balanced images lack such grouping into closed shapes and often lack recognized shapes at all. In these cases perception of the global figure alters entirely with rotation. These characteristics are consistent with previous suggestions that balance is perceived through global processes (Locher 2003; Locher and Stappers 2002; Locher et al 1996, 1999; Nodine et al 1993).
- **Imprecision of location of grouped forms.** Within the most balanced sets rotation alters the perceived nature of a line and in effect alters its perceived location and grouping with other lines and its perceived weight. When grouping results in completion or closure of rectangular shapes, while rotation reduces balance within the stimulus set, it does not change perception of these shapes: a square (at 0° rotation) will still be perceived as the same square although standing on its corner when rotated by ±45°.
- **Diagonal shapes.** Across stimulus sets the individual images that are least balanced are those with salient elements or grouped figures that are diagonal. Yet, within this group the images with diagonally positioned closed shapes are perceived as more balanced than those of open, curvy, unfamiliar shapes.
- **Object recognition.** Complex groups add to balance when they are easily recognized as meaningful objects. For example, in the stimulus set of image 1 (Figure 9a) the 45° rotation turns the dominant diagonal elements into horizontal and vertical elements that resemble the shape T, leading to an increased balance rating. Similarly, image 9 resembles a gate, 10 a large person, 15 a person besides a tree, 7 the moon, and 1 a walking person, as their Japanese pictograph names suggest. These content meanings (or other such meanings) may have been picked up implicitly by our non-Japanese-reading participants. This element of content is also found in preference studies, showing that meaningful content determines preference more than do formal features (Martindale et al 1988, 1990; Purcell 1984; Whitfield and Slatter 1979).

Thus, our observations lead to the conclusion that for balance processing at first glance, at least for Japanese calligraphy by non-Japanese readers, global grouping effects are essential and elementary for both artists and novices. These include vertical symmetry, closure and completion, and presumably recognition of familiar forms such as the T shape. Moreover,

already at first glance, art experts differ from novice viewers: with art expertise, local elements (such as a wide base; see Figure 10) are also processed rapidly. These local elements interfere with global perception and influence pictorial balance judgment. Art expertise balance judgment had improved consistency and was amplified compared with novice balance judgment. In summary, our observations show that statistical analysis of image attributes—such as area weights based on a framework of fixed symmetry axes, directionality, or center of mass—does not seem to suffice for balance assessment.

5 Conclusion

Pictorial balance studies in art theory drew on the notion that balance is a structural set of relationships, including formal attributes, such as size and color, and content-based attributes, including interest and symbolism. Perhaps owing to the difficulty in experimental control, balance perception studies gradually emphasized formal attributes, ignoring content-based elements. Despite the finding that balance perception occurs already at first glance (≤ 100 ms), research focused on the aesthetic experience for long viewing periods, which enabled eye movements and interference of later cognitive processing. The present study focused on balance processing at first fixation.

The main conclusion of the current study may be expressed as "meaningful content before form". In other words, we find that even at first glance "meaningful content makes the form" is a chief pictorial balance computation principle in the case of Japanese calligraphy (see preceding section, Object recognition). We suggest that this may extend to other forms of art as well and be even more significant in art where emotional content plays a role as previously shown for aesthetic preference (Kaplan et al 1972; Martindale et al 1988, 1990). This principle means that as early as first fixation the weight of an image element is computed based on its contextual meaning and not solely on its formal attributes, such as size, directionality, hue—and not only in relation to distance from image center or location in the symmetry axis framework, as predicted by reverse hierarchy theory (Hochstein and Ahissar 2002). Rather, rapidly perceived weight and balance may derive also from global features.

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