Art: A Covert Eye-Centering Principle in Classic Portraiture

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Introduction

The importance of the center of the canvas has long been appreciated in art (1). There are rules of artistic composition that highlight the importance of the central vertical line in various ways. How are such rules applies to the field of portraiture? There seems to be no mention of compositional rules for the placement of the eyes in relation to the frame of the canvas. This is a remarkable omission in light of the present results, which reveals a high consistency in the placement of the eyes relative to the picture frame in portraits through the epoch of secular art (the past 600 years).

The goal of the study is to quantify the relation between eye position and the frame of the canvas. The method is to measure the horizontal and vertical position of the eyes in portraits available from various sources. The placement of two eye-position parameters will be evaluated. One is the position for the center of symmetry between the two eyes in portraits where both eyes are visible. This center of symmetry of the face is often discussed in art analysis (2-5) and may be expected to be used as an explicit compositional primitive by artists trained according to such analysis. However, I have not found a source that discusses the placement of the facial symmetry axis in relation to the canvas.

The second parameter is the placement of one the eyes in relation to the canvas. Again, eye placement does not seem to have been explicitly discussed, at least in the more widely cited reference works. The single-eye placement hypothesis was evaluated formally by defining the most-centered eye of a portrait as the one closest to the vertical center line. Since the result of the analysis will be to show that this eye does lie systematically close to the center line, this definition may appear to be unnecessarily circular, but this is not the case. First, we need a criterion for which eye to select that applies to all portraits and does not rely on aesthetic judgments, on which there may not be universal agreement. Second, if eyes are positioned according to the first hypothesis, of positioning the center of symmetry of the two eyes in relation to the vertical axis, both eyes will be the same distance from the axis and the choice of eye will make little difference to the result. Finally, if the head is positioned in a random distribution centered on the center vertical, choice of the closer eye as the one for analysis will narrow the distribution somewhat, but by no more than a factor of 1.41 (the square root of 2), the standard deviation of the minimum value of two samples from a Gaussian distribution.

To illustrate the degree to which an eye tends to be set near the center vertical in portraits, twelve classic portraits from the past six centuries were selected for reproduction in Fig. 1. Selection for this figure was based on the artistic significance of the portraits with the heads in a variety of poses, with no attempt at a scientific sampling. From the perspective of frame geometry, many of the examples illustrate the lengths to which portrait artists seem to go to set one eye on the center line, even when they depart from the classic three-quarter pose. Several cases illustrate how clever composition generates the overall impression that the face is symmetrically located in the frame. Only when the guide lines are drawn through the pictures does it become clear that one eye is near the exact horizontal centre.

Fig. 1. A selection of classic portraits over the past six centuries, illustrating the degree to which one eye tends to be placed on the center line. The portraits are reproduced to the full width of the original frame (with the exception of that of George Washington, from the $1 bill) and cropped at the bottom to match an arbitrary vertical dimension. The white line runs down the horizontal center and is broken where it reaches the level of the most-centered eye. The examples were selected for the variety of poses and asymmetry of the compositions. Such eye-centering is typical of the majority of portraits, as is shown by the analysis of the full data set. Portraits are by Rogier van der Weyden (c. 1460) Sandro Botticelli (c. 1480), Leonardo da Vinci, 1505), Titian (Tiziano Vecellio; 1512), Peter-Paul Rubens (1622), Rembrandt van Rijn (1659), Gilbert Stuart (c. 1796, as reproduced on the U.S. $1 bill), Graham Sutherland (1977) and Pablo Picasso (1937).

Lateral Placement of the Eyes in Portraits

To perform a scientific survey of this compositional principle, portraits were gleaned from a variety of published summary sources (4-11). The idea was to choose compendia that contained a large number of reproductions of hand-composed portraits, using all those portraits from each source that fit a set of criteria. Since the publications were using the portraits for a variety of historical and artistic purposes, there was no reason to suppose that there was any sampling bias in their selection in relation to the present positioning hypotheses. A preliminary survey indicated that there was little tendency to center an eye in side-view or profile portraits (as in coins, medallions, stamps and so on), so these were excluded from the analysis.

The histograms of Fig. 2 vividly illustrate how one eye is placed in a narrow distribution peaking at the lateral center in portraits over the centuries. Although this position conforms with some expectations from previous compositional principles, consideration of the variety of hypotheses from the artistic literature (see Figs. 3 & 4) implies that it would have been difficult to foresee this outcome before the study was conducted. In particular, many portraits are designed with an asymmetric composition that makes it hard to evaluate the symmetry of the eyes in the frame. Thus, it seems that the centering of one eye is appreciated at some subconscious level in the brain, while hidden from the domain of conscious judgments. In fact, a survey of classical texts on composition has failed to reveal any mention of the idea that the eyes as such should be positioned relative to the frame of the picture; the typical emphasis is on the placement of centers of mass or relative to the vanishing point in cases of central perspective (1-5, 12-18)

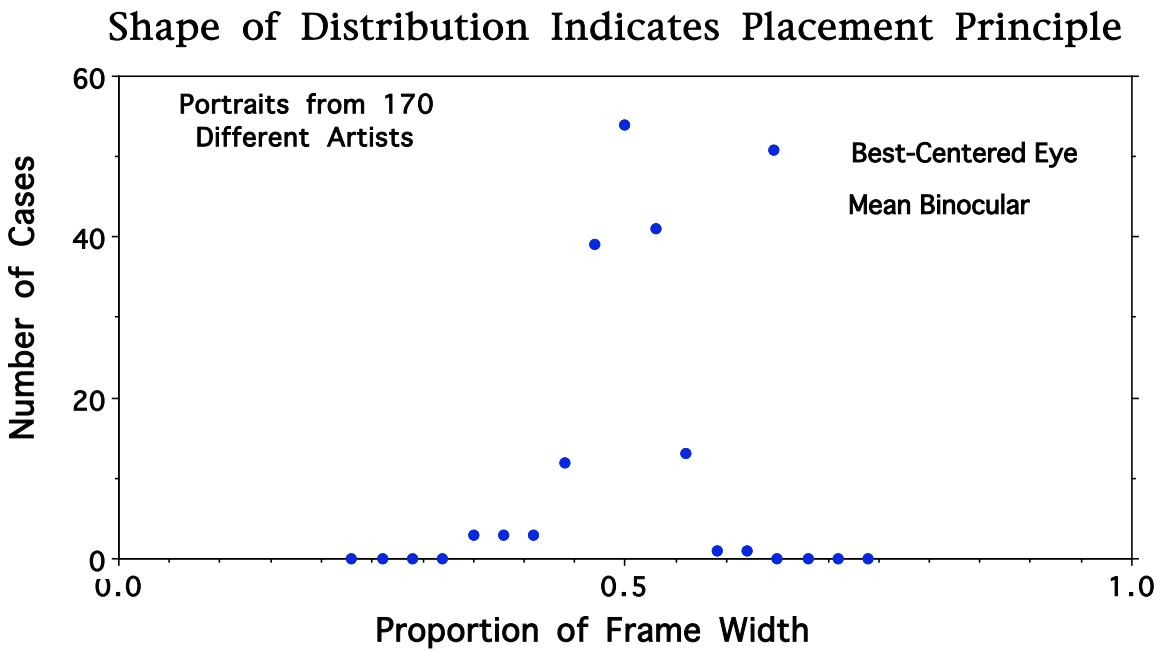


Fig. 2 . Histograms of lateral location of the best-centered eye (filled symbols, solid curve) compared with the mean binocular position (dashed curve) in portraits over the past 600 years. The position of an eye was defined as the position of the center of the eye opening, regardless of the position of the pupil. Note the narrowness of the best-eye distribution, with a standard deviation of only $\pm$ 5% of the frame width. Conversely, the mean binocular distribution (of the positions of the point halfway between the eyes in each portrait) shows a bimodal distribution, as expected if one or other eye were centered. (The mean binocular distribution is significantly deviant from a Gaussian distribution at $p < 0.01$ on the chi square test, whereas the best-centered eye distribution is well fit by a Gaussian at $p > 0.1$.) If the centering were based on the pair of eyes rather than a single eye, the opposite pattern should be obtained; the mean binocular distribution should be unimodal and the best-centered eye distribution bimodal.

The portraits were selected as the first portrait by a given artist in each source (4-11) meeting the following criteria: that the portraits were drawn by hand (oil paintings, watercolors, drawings or engravings) to ensure that the artist had maximum control over the composition; that there was only one person in the portrait; that both eyes were visible; and that depiction of the body did not go below the waist (to ensure that the head rather than the figure was the principal element of the composition). The sources were non-overlapping, so that only one portrait was included by each of 170 artists in the sample.

In this regard, it is interesting to compare the accuracy of placement with that in a psychophysical study of error in the placement of elements within a frame (18). Reproduction of the position of a single dot was accurate to about $\pm$ 2% of frame width, while accuracy fell to about $\pm$ 5% for the placement of 4 or more dots simultaneously. It therefore seems that the unconscious (or unexpressed) placement of the eye in artistic portraits is nearly as accurate as the attentive performance of those who were focusing on positioning as their sole perceptual task.

Two-Dimensional Distribution Hypotheses

Having analysed the lateral distribution, the study would be incomplete if it did not consider the full two-dimensional distribution of the feature positions within the portrait frame. In addition to the eyes, it is also possible that other prominent features such as the mouth might play a dominant role in the positioning of the face. The study will therefore use mouth position as a comparison parameter. Before performing the empirical analysis, it is salutary to depict potential hypotheses for compositional elements such as eye position on the basis of the explicit analytic framework of artistic composition. One such compositional tool is the major frame axes shown in Fig. 3a. According to this analysis, one of the two eye-placement parameters might be expected to be positioned according to this framework. Of course, the dominant focus here is the exact center of the frame, generating the competing hypotheses that either the center of symmetry or the closer eye should be tightly distributed around the center of the frame. in discussion of composition, the most important of the four axes is the vertical, so another hypothesis is that one of the two eye parameters would be commonly located near the vertical axis. On the other hand, there is much artistic effort to build a degree of asymmetry into the composition (as typified by the three-quarter view in portraits), so one might equally hypothesize that the vertical would often be avoided. In relation to the analytic framework of Fig. 4a, this elaboration might be hypothesized to lead to the tendency to position one of the two eye parameters close to one of the diagonals in the frame, or somewhere along the horizontal center line.

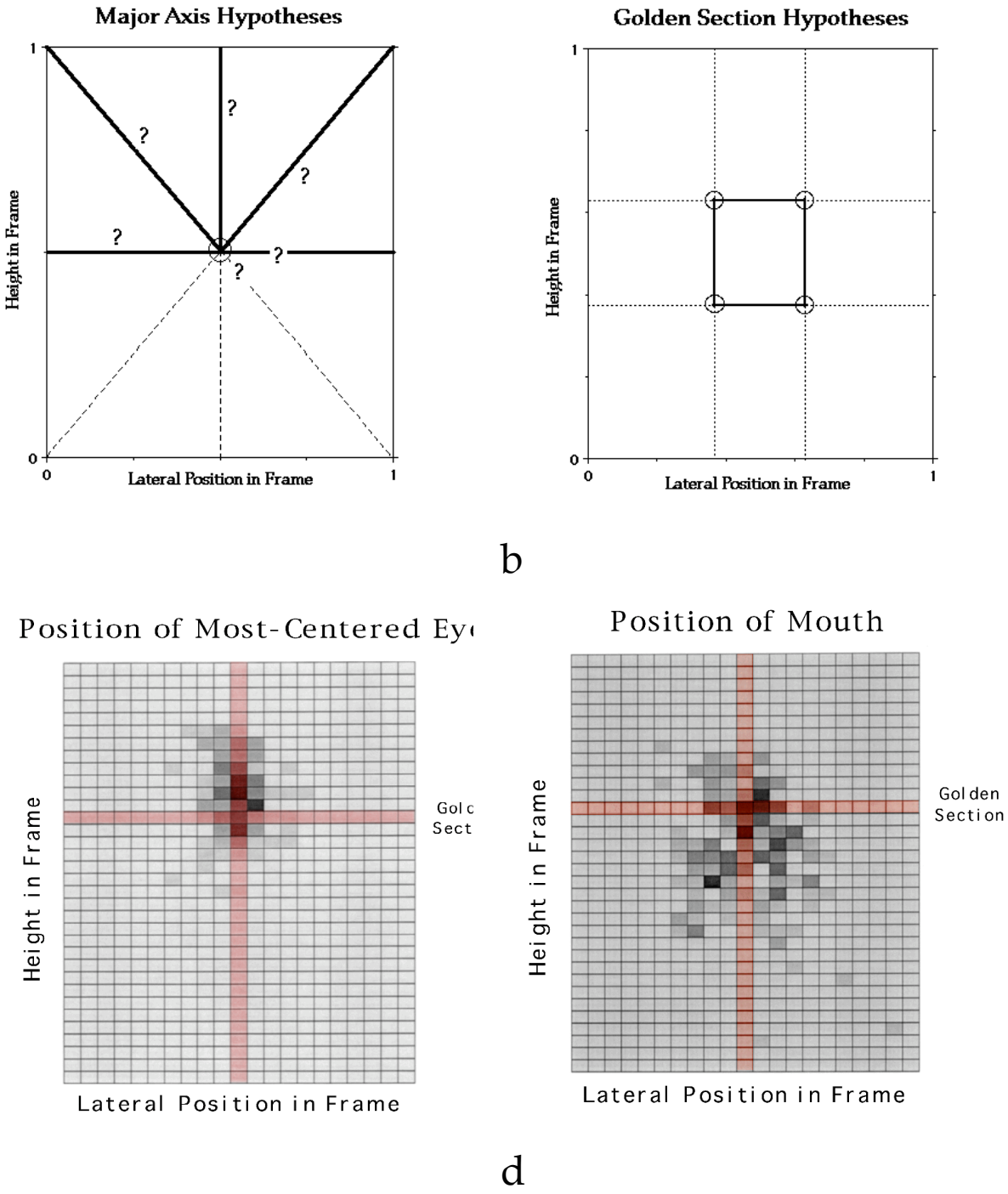


Fig. 3. Classic compositional principles for positioning figure elements with respect to the frame, and empirical feature distributions in portraits. a. Major cardinal and diagonal axis of frame, intersecting at the geometrical centre. b. The four Golden Section lines, forming a Golden Square at the centre. c. Two-dimensional histogram of position of most-centered eye in portraits (defined as for Fig. 2). d. Two-dimensional histogram of position of mouth in portraits. Rose lines indicate center vertical and upper Golden Section, which intersect close to the center of the eye positions in c. Mouth distribution is scattered more broadly around the geometric center of the frame. Mouth distribution cannot therefore account for the tight distribution of eye positions.

An alternative framework of great antiquity is that of the Golden Section, a dividing ratio of 0.6180 at which the ratio of the smaller segment to the larger is equal to the ratio of the larger section to the whole. There are four such sections forming a central rectangle (Fig. 3b), with the upper vertical corner being the dominant one. If this principle plays a role in portrait composition, we might hypothesize that one of the two eye parameters would be centered on one of these Golden Section lines, or alternatively within the central rectangle that they define. In fact, it has often been proposed that the upper right corner of this square was a particularly important visual focus (e.g., 17), so positioning on that corner would be a particular subcase of the Golden Section hypothesis.

Two-Dimensional Distributions of Facial Features in Portraits

The two-dimensional placement of the most-centered eye may be compared with that of the mouths in the same set of portraits as are analyzed in Fig. 2. Two-dimensional gray-scale histograms of these features (Fig. 3a & b) show that the eye is more accurately placed than the mouth (especially in the lateral distribution), that the mouth lies around the center point while the eye is almost always above it, and that the eye height falls close to the upper intersection with the Golden Section. The tightness of the eye distribution indicates that it is not positioned as a consequence of its geometric relation to a centered mouth, but must have separate placement principles that give it a more accurate localization.

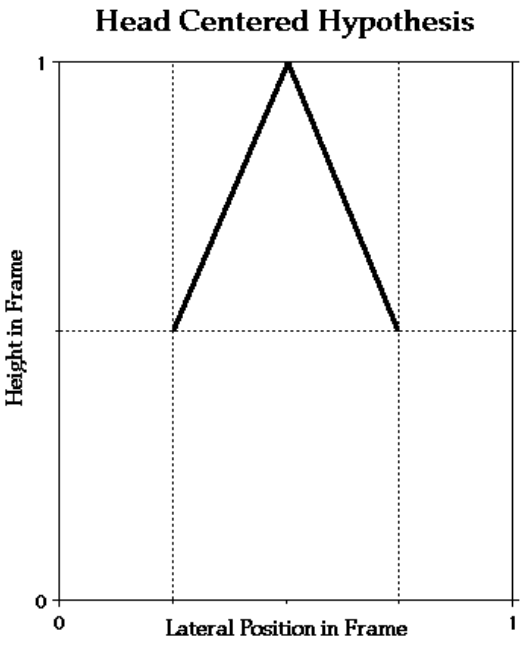
Scaling of Eye Position With Scale of Portrait

One factor in the greater extension of the eye distribution vertically than horizontally may be the fact that the portraits had a range of scales, from those in which the head filled most of the canvas from edge to edge, to those that include the body down to the waist. It seems natural to move the head up in the frame as more of the body is depicted, to avoid having a space above the head equal to the extent of the body depicted. Such a principle would increase the vertical spread of the distribution without affecting its horizontal extent. (The tendency to move the head up in the frame as more of the body is depicted is not a necessary corollary, merely a plausible one. It could be that good composition called for the head to be centered vertically and the space above it to be filled with some relevant compositional feature for balance. An informal survey suggests that this approach may typically be adopted in practice in portraits of children as opposed to adults. An example is the famous picture of the *Infanta Margarita Theresa* by Diego Velazquez, where head of the Infanta is well below the midline.)

To evaluate the role of such a scaling principle in eye placement, the range of scales was extended by adding from the same source books the set of single-figure studies that included portions of the body below the waist. This full range of figural studies now require evaluation of eye position principles, which will be structured in terms of the positions of the two eyes separately to remove the small narrowing of the distribution laterally by the choice of the most-centered eye in Figs. 2 & 3.

In addition to the general positioning principles of Fig. 3, a further set of hypotheses may be adduced from the geometry of the head within the frame. If the whole head is to be centered laterally, the result would tend to be a centering of the eyes for portraits in frontal view. The scaling of the figure as more of the body is included in the portrait, in addition to pushing the head higher in the frame, will necessarily

involve scaling the distance between the eyes down proportionately. With the head centered in the frame, the result of the scaling of the body geometry should be an inverted V shape proportionality of eye position (Fig. 4a). This prediction may be considered to follow from a common artistic principle of composing according to the "negative space" or perceptual ground behind the figure. If the composition of negative space around the head is symmetrical, the head will be centered laterally in the portrait frame.



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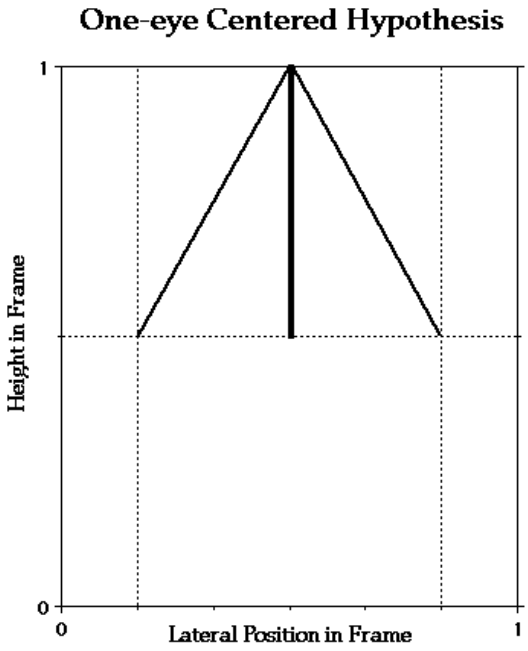

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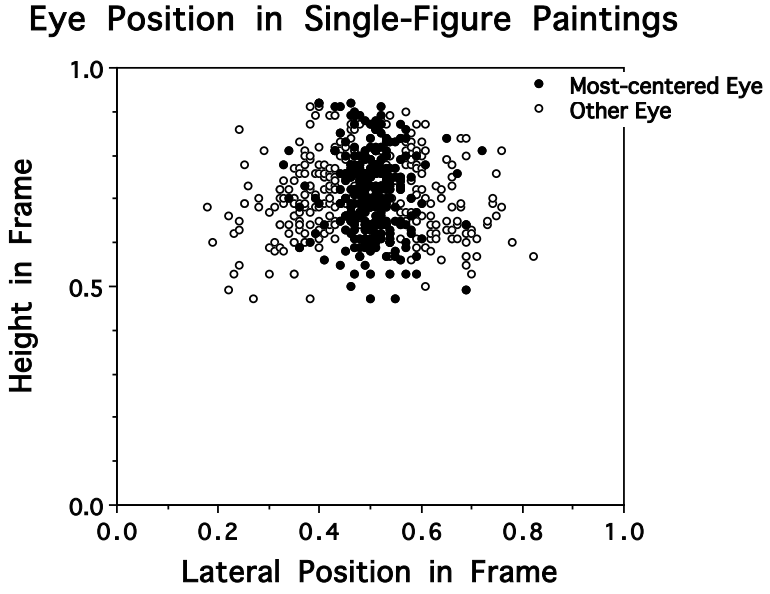

c

Fig. 4a. Two-dimensional distributions in single-figure studies, which allow a wider range of head sizes. a. Eye-position loci on head-centered hypothesis forms an inverted V-shape on the assumption that head is placed near top of picture. Width of configuration is plotted up until face fills frame, assuming that the eyes are halfway down the head outline. b. Eye-centering hypothesis predicts tripod arrowhead configuration of eye-position loci on the same assumption. If one eye is centered, head must be situated to right or left, allowing a somewhat broader base to the distribution. c. Two-dimensional positions of eyes single-figure studies from 282 different artists over the past 600 years. The figure studies were selected according to the same principles as the portraits of Fig. 2, except that all figure lengths were included. Thus, only the first painting by a given artist was taken from each source, so that there is only one painting by each of 282 artists in the sample. The proportions of all paintings were normalized for combination in this figure, so that the positions are shown in terms of proportion to each frame dimension for the particular painting, regardless of its actual aspect ratio. The most-centered eye is shown by filled symbols, the other eye by open symbols, a circle if to the left, a square if to the right in the image. Virtually all the eyes were located above the centre, excluding the centering geometry of Fig. 3a as the organizing principle. However, except for a sparse fringe of less-centered positions, the most-centered eyes are clustered around the center vertical, so that this geometric element appears to play a key role. None of the other major axes or the Golden Section square of Fig. 3b seem to account for any of the eye placements. Considering the positioning of all eyes, the pattern of distribution is closest to arrowhead pattern of the scaled centering of one eye on the center vertical, depicted in Fig. 4b, rather than the inverted V-shape of the head-centering principle of Fig. 4a.

A possible role of the Golden Section principle is depicted by the dashed lines. The lower dashed line represents the Golden Section height of the painting, which corresponds roughly with the lower range of the eye position distribution. The upper dashed line represent the Golden Section of the upper rectangle defined by the lower dashed line, a "Golden Subsection", which roughly demarcates the upper range of eye placements. Thus the artists allowed a much broader range of vertical eye positions than horizontal ones (for the most centered eye), but tended to keep them within the quarter of the height range lying between the Golden Section and Golden Subsection levels.

The final compositional principle shown (Fig. 4b) is the one derived empirically from the results reported rather than being based on known principles of compositional analysis. This is that one eye is centered on the horizontal midline (presumably at or above the vertical centre, since the eyes are about half-way up the head). Again following the body-scaling principle for the head placement, the result will be that the second eye falls in an inverted V, so that the combined locus of the two eyes should form a triangular arrowhead configuration.

There are thus a dozen or more hypotheses that could be drawn from current art analysis as to the scaled positioning of eyes in single-figure studies (in addition to the null hypothesis that there is such a variety of influences that the eyes will be positioned in a broad distribution that merely avoids their going too close to the edge of the canvas). The results of the measurements of 282 portraits and full figure studies are shown as the scatter plot of Fig. 4. It is immediately obvious that one eye is centered in a tight distribution around the vertical axis, conforming to the one-eye centered hypothesis of Fig. 4b rather than the head-centered hypothesis of Fig, 4a. The distributions of the 'other' eyes (either to the left or to the right in Fig. 4c) fall near the oblique lines of the 'arrowhead' configuration, although its base is narrower than that of the prediction in Fig. 4b. The relative spread of the 'centered' and 'other' eyes allows evaluation of a further hypothesis, that the centering of one eye is a result of the combination of two other principles. Perhaps the head is centered but the face turned obliquely to the favored 3/4 view, providing a better impression of the profile in addition to the frontal features. If this combination of factors were the dominating

principle, the spread of the distributions of both eyes should be equal. Since the distribution of the centered eye around its (vertical) scaling line is narrower than the distributions of each of the other eyes around their scaled loci (oblique lines), we may conclude that there is a significant tendency for one eye to be centered, over and above the combination principle.

The data thus clearly repudiate the null hypotheses of a broad distribution of eye position parameters and several of the principles expressed in art analysis, such as a focus at the center of the canvas (1). The vertically displaced centering that is evident in Fig. 4c is reminiscent of the peak of the distribution of initial eye fixation positions in a study of free-viewing of scenic images (20). From the examples given in that study, the images did not appear to have a dominant focal element at the peak position with greater probability than any other, but the fixation histogram had a single peak centered laterally and at about 0.6 of the image height vertically. Thus, the placement of an eye at this position in portraits may be associated with a higher probability of looking first at this same point, although it is difficult to disentangle the causal relationships between the compositions and the eye fixations without further experimentation.

On the other hand, one type of portrait that is identified as not adhering strongly to the same principles is the side view of the head. In the smaller sample of side views from the same sources (4-11), the eye positions are scattered widely throughout the frame. Moreover, the vertical position of the eye now shows a tendency to be set in the middle of the frame rather than at the level of the Golden Section. What it is about side views that changes the rule of composition is not obvious. Perhaps, now that the subject's attention is perceived as being focussed away from the viewer, the dominant principle becomes the centering of the head in the frame because it is the key feature of the composition.

In summary, the analyses presented reveal a dominant positioning principle for one eye in a portrait to lie on the vertical axis at or above the Golden Section level. The center of symmetry, which is the explicit organizing feature in many analyses of portrait technique, plays only a minor role in the composition. That the present results show that explicit compositional principles are implemented with an unbiased accuracy of $\pm$ 5% over the past six centuries is remarkable enough. The fact that this precision has been obtained from perceptual processes that appear to be completely unconscious to the artists themselves suggests that hidden principles are operating in our aesthetic judgments (and perhaps in many realms beyond the portraiture that is the topic of the present study).

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to first generate the combined cumulative distribution as the product of the two individual distributions, then take the derivative of this product. This result is a distribution for the closer eye that is narrower by root 2 than the (equal) individual-eye distributions.

Thus, to provide a quantitative estimate, suppose that the constraint of having the head remain within the frame gives the mean head position (i.e., the center of symmetry of the eyes) a standard deviation of 20% of the frame width. The eye closer to the vertical would then have a distribution with a standard deviation of 14% of frame width.

It should be noted that histogram distributions appear to reveal some fine structure, in that the narrow peak is flanked by a broad base, representing a subset of the portraits that did not adhere to the narrow positioning principle. This feature is too detailed for analysis in the present treatment, but it would exemplify the tenet that all rules in art are creative guidelines that can be ignored for a appropriate compositional requirements.

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