

Some principles of spatial organization in art

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Abstract—Rules of composition in paintings form a rich probe into the principles of perceptual processing that have been discussed for centuries. These principles can be studied by controlled scientific experiments, but an alternative approach is to use the art works themselves as a database for direct analysis. This paper focuses on the analysis of composition in relation to the canvas frame. An underlying principle is the compositional pyramid rising from the bottom of the frame to a center of consciousness high on the midline, which also finds its expression in the configuration of portrait paintings. The analyses presented reveal a dominant positioning principle for one eye in a portrait to lie on the vertical axis with an unbiased accuracy of the order of $\pm 5\%$. Analysis of the vertical location shows that the dominant height is at or above the Golden Section level on the vertical axis. In general, the layout of the portrait follows the principle of the compositional pyramid, with a center of consciousness at its apex, but there are many other compositional principles at work in the corpus of portraits in general. Analysis of the portraits of particular artists reveals that special features of their work must be considered in order to identify those that do and do not conform to the eye-centering principle.

Keywords: Art; painting; composition; principles; portraits; eye-centering.

INTRODUCTION

The rise of knowledge in the field of neuroscience has given new impetus to the exploration of connections between art and the brain (e.g. Blakeslee, 1998; Kawabata and Zeki, 2004; Ramachandran and Tyler, 1999; Zeki, 1999). The common preconception of neuroscience is its focus on ‘wet’ neurophysiology, the study of neurons, synapses, transmitter chemicals, cellular structures, genetic coding and so on. These are the underlying constituents of the corpus of neuroscience that attract the most attention. But there is a new level of analysis that is being developed for some of the highest levels of integrative functioning of the brain. This kind of analysis looks for the principles of operation of the mind, under the guiding rubric that what has

been conceptualized as the mind is, solely, the functioning of the brain. At this level of conceptual analysis, the goal of integrative neuroscience is to explain functions such as perceiving (color, space, motion, form, facial expression and so on), and more abstract functions such as thinking, problem-solving, and consciousness. This level of brain function is now regarded as a legitimate target of neuroscience studies, the exploration of paradigms to manipulate aspects of consciousness and determine the brain processes underlying its activation. It is at this level of analysis that neuroscience seems to have the best opportunity to intersect with the mode of art.

One type of linking question is whether there are general neural principles underlying particular aspects of art appreciation. This question has been approached in art analysis by such figures as Erle Loran and Rudolph Arnheim, in their studies of the organizational principles of spatial composition (Arnheim, 1954; Loran, 1963). While their analyses of implicit structure and motion in the composition of pictures have intuitive power, there has been no scientific basis for either the derivation of the principles or the range of their use in art practice. This kind of intermediate study would be needed before the neural basis of such principles could be established. In terms of perceptual analysis, the principles developed by Arnheim (1954) remain a powerful stimulant to empirical study and theoretical analysis. One example is the lines of force and equilibria generated by an outline square (Fig. 1). His empirical study was the consensus of group observations in art classes, and his analytic basis was the theorizing of the Gestalt psychologists in terms of neural force fields in primary visual cortex.

Much of the Gestalt conceptualization was discredited by neurophysiological studies (e.g. Lashley *et al.*, 1951), which purported to show that it was simplistic at best and fundamentally misleading at worst. However, the organization of

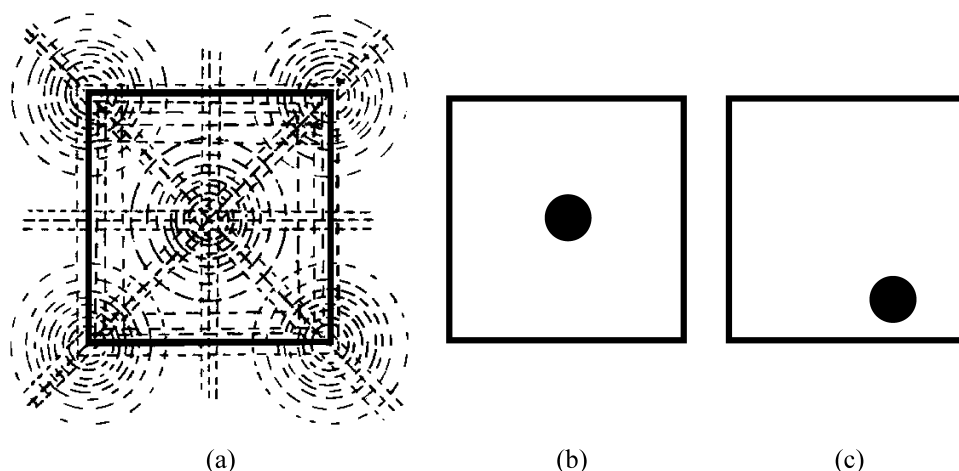


Figure 1. (a) Fields of attractive force around a square figure (from Arnheim, 1954). (b) Centered dot has stable percept. (c) Off-center dot creates perceptual 'force' to move it to a stable location.

cortical connections is highly complex, and may rely on connectivity among cortical regions and between cortical and subcortical regions as much as within a given cortical region (Bair *et al.*, 2003; Van Essen, 2005). Although far from a complete analysis of neural connectivity, these studies reveal that it was the ‘disproof’ of Lashley *et al.* (1951) that was simplistic, and that there is plenty of room for the neural instantiation of force fields underlying the perceptual organizations of the Gestaltists, even if not in the original form of cortical fields that they were envisaged. For example, the forces identified by Arnheim (1954) could be operating in the secondary and tertiary retinotopic areas of occipital and parietal cortex rather than in V1 (where Lashley’s studies were conducted), or in the reticular or pulvinar nuclei of the thalamus, or in the eye-movement control regions of the frontal eye fields, the superior colliculus or the cerebellum, all of which have extensive connections with the early form processing regions of the cortex. The complex interplay of perceptual processing among these many and various visual processing regions will require to be addressed with great experimental sophistication before they are fully understood.

THE ROLE OF COMPOSITIONAL PRINCIPLES

We may identify four ways in which compositional principles may be used by artists in their painting practice.

- (i) Slavish adherence to an explicit principle of composition. This structured approach tends to be found in artistic fields such as design, graphic layout, architecture and scenography. An example is symmetry of placement. In the layout of designs in books, on coins, in buildings, etc., the principles of perfect symmetry or accurate alignment are often applied.
- (ii) Explicit approximation principles, e.g. balance, resonance, symmetry, and other principles that are approximated by the shapes and masses in the paintings without adhering rigorously to particular geometric properties. In many cases it is difficult to specify the boundaries and weights of the masses precisely, yet trained observers agree on the operation of the principles in novel instances.
- (iii) Explicit anti-principles. The avoidance of some compositional arrangement by unspecified means, e.g. the avoidance of symmetry is a compositional principle that is often expressed in painting manuals.
- (iv) Implicit principles. Many forms of compositional structure are embodied in works of art and transmitted by art practice without explicit specification (at least as far as can be ascertained from published material).

One form of the implicit principles is the rules of operation underlying the perceptual lines of force, which have been established in a series of empirical studies stemming from Blum (1973), by Igel and Harvey (1991), by Kovacs and Julesz (1994) and Kovacs *et al.* (1998) and by van Tonder *et al.* (2002). This is the

medial axis representation of shape, achieved by condensing any form to its stick-figure 'skeleton' running down the center of each elongated segment of the figure. Since the medial axis does not exist in the image, any perceptual activation of this form must represent an underlying neural process. Moreover, since the medial axis is not visible perceptually, or directly available to consciousness, its operation in guiding perceptual processes and a sense of rightness of spatial placement must be subconscious or 'pre-attentive'. Such pre-attentive processes form a key point of intersection between art and neuroscience.

THE COMPOSITIONAL PYRAMID

One of the classic principles of painting structure is the compositional pyramid (discussed by Poore 1903, followed by Curtius, 1929; Berger, 1963; Kent, 1995 and Puttfarcken, 2000). The idea is to structure the important elements of the scene into triangle, or pyramid, with its base coincident with the bottom of the frame. Although it has been widely recognized in art criticism, it is hard to find a comprehensive statement of the rationale for this compositional scheme. The explanations that one does find have a *post-hoc* flavor, a sense of justification after the fact rather than an analytic account of its underpinnings. For example, most accounts emphasize the sense of stability and repose that are provided by the pyramidal scheme, despite the fact that it is used in some of the most active, dynamic compositions in the history of art. To make this point, two contrasting uses of the compositional pyramidal are reproduced in Fig. 2, from Raphael and from Gericault. These paintings illustrate how the pyramid form transcends the activity level of the scene — it is equally applicable to scenes of motherly love and of the terror of a shipwreck.

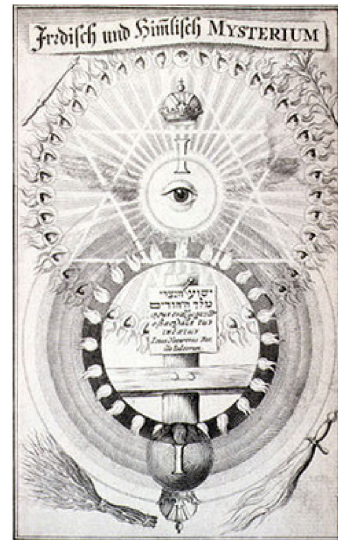
One clue to the role of the pyramid lies in the origin of its name. Although not generally recognized in etymological sources, it seems that the term must ultimately derive from pyre-shaped, from the Greek 'pyra' for a funeral pyre. It is the piling up of the kindling wood that forms the pyramidal shape, and which may have given rise to the original form of the stone pyramid for disposal of the dead. A classical case was the funeral of the licentious Paris, whose seduction of Helen caused the fall of Troy in a ten-year siege in the 11th century B.C., and who was cremated on a burning pyre. Hercules, also, was about to be cremated on a funeral pyre before he was saved by his father, Zeus. But the core concept of the pyre is a fire that frees the spirit from the ashes, in a sense giving life to the dead. Rather than repose, the pyramid shape may evoke a concentration of forces with the flame at its heart. Certainly, the mystic interpretation of the pyramid gives it this role, and further attributes a variety of growth and healing power to the pyramid form *per se*. These are different and more potent concepts than the sense of stability and repose that is traditionally attributed to the ubiquity of the pyramidal composition in art.

Figure 2. (See color plate V) Examples of the compositional pyramid, from serene (Raphael, 1505) to dramatic (Gericault, 1780).

The concepts of spirit and power associated with the pyramid are neatly encapsulated by the symbol on the great seal of the United States of America, reproduced in Fig. 3a, possibly configured in the form of its initial letter, A. Though often as-



(a)



(b)



(c)



(d)

Figure 3. Symbolic uses of the pyramid composition. (a) The Eye of Providence overlooking a truncated pyramid (William Barton, 1782). (b) The Eye of Providence centered in a triangle (Jakob Boehme, 1620). (c) The Sun God, Ray, at the apex of the pyramidion of Bennebenshauf (~1000 B.C.). (d) Jesus overlooking the Celtic House of Worship (from the Book of Kells (~900 A.D.).

sumed to be derived from Egyptian symbolism, the particular configuration of an eye at the apex of a pyramid appears to be original to William Barton, the designer of this seal. He certainly had access to the works of Jakob Boehme, a Christian mystic of the previous era who made extensive use of the symbol of an eye in a pyramid, or triangle, as exemplified in Fig. 3b. Indeed, this image of the eye in a triangle at the center of the solar radiance may be traced back to a motif in the jeweled cruxifixion statuette that was originally made for Phillip the Bold by the goldsmith Herman Ruissel in 1402 (Kovacs, 1983). But Boehme always placed the eye at the center of the triangle, while the Egyptians often placed the sun near the apex in an evocation of the power of the sun god, Ray (Fig. 3c). (The Egyptian sun god is usually rendered as Ra, but the intended pronunciation is 'ray', so it seems that we may avail ourselves of the apposition of the English meaning of this word in making the pronunciation explicit.)

There is also an example of Jesus overlooking the house of worship in the Book of Kells that utilizes this composition (Fig. 3d), although it is at the moment that he is resisting temptation by the devil, so it is not clear that he is in a protective mode. Thus it was the freemason Barton who combined these themes to depict the 'eye of providence' overlooking the good work of the pyramid, representing the vocation of construction (Fig. 3a). Despite its precursors, this specific design is an entirely novel juxtaposition epitomizing the birth of the new nation under the eye of a watchful guardian. The symbol is now promulgating widely under the influence of its ubiquity in the American icon of the dollar bill.

How does this quasi-mystical symbolism relate to composition in art? Customarily, art avoids the explicit symbolism of heraldry and mysticism as too 'obvious'. The well-spring of the art mystique is to retain an ambiguity of interpretation, to keep us guessing and continually reinterpreting in a rich overlay of possible meanings. To do so, it needs to draw on symbolism and iconic imagery and to build a structure of interpretive meaning, but to use it in implicit fashion as part of the composition of other elements (such as the characters in the action). In this manner the compositional themes evoke the power of the pyramidal structure without making their depiction explicit. But the power of Barton's symbol in particular is that it captures a further level of interpretation by placing a consciousness at the pinnacle of the triangle in the form of an eye. The sun god at this locus evokes power, but the eye evokes awareness, a distinction derived from the extromission versus intromission of light rays at the peak of the pyramid.

In the composition of paintings, artists can avail themselves of these interpretations by including a source of power or awareness at this locus of the composition. Once alert to the possibility, we find that this motif is a common theme of the pyramid composition. Where art theorists have pointed only to the triangular form, we can recognize the extra level of exposition in the placement of a source of consciousness, a guardian or observer of the action, at this apical location. However, the importance of placing a motif of consciousness below the apex of the pyramid may not be an explicit rule that is expressed in studio training, but a practical recognition

learned by trial and error that the composition becomes more effective when the figure of an observer is placed at this location relative to the compositional triangle, with the result being subtle enough to escape codification into a formal rule.

Examples of inclusion of an observer of the action at the apex of the pyramid composition are given in Fig. 2, while examples of the power source are usually in the form of a light source or lighthouse. It is an interesting exercise to survey a gallery of paintings and see how many examples of such compositional themes are to be found, and the variety with which they are employed.

AN EYE-CENTERING PRINCIPLE

In a previous report, I described the prevalence of a tendency to center one eye in portraits over the past six centuries (Tyler, 1998). To illustrate the degree to which an eye tends to be set near the center vertical in portraits, a set six portraits of four centuries of the Murray family is reproduced in Fig. 4. The artistic styles vary considerably, each being characteristic of its period, but one constant is the tendency



Figure 4. A set of portraits of one family, the Murrays, painted over the past four centuries, from the Scottish National Portrait Gallery, illustrating the degree to which one eye tends to be placed on the center line. The portraits are cropped at the bottom to match an arbitrary vertical. The white line runs down the horizontal center and is broken where it reaches the level of the most-centered eye. (Reproduced from Bruce and Young, 1998; Scottish National Portrait Gallery.)

to center one eye in every case. The relation of this centered eye to the eye at the apex of the pyramid will be developed in due course.

The importance of the center of the canvas has long been appreciated in art (Arnheim, 1954). There are rules of artistic composition that highlight the importance of the central vertical line. Equally, in portrait paintings, emphasis has been placed on the axis defined by the center of the face. But there seem to be no known compositional rules about the placement of the eyes in relation to the frame of the canvas. This is a remarkable omission in light of the results of Tyler (1998), which reveal a high consistency to place one eye close to the center vertical to the picture frame in portraits through the epoch of secular art (the past 600 years).

The goal of the study was 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 (starting with Goldwater and Treves, 1945, followed by Arnheim, 1954; Edwards, 1989 and Jaxtheimer, 1982) and may be expected to be used as an explicit compositional primitive by artists trained according to such analysis.

The second parameter is the placement of one of the eyes in relation to the canvas. This principle 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 the 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.

In a scientific survey of this compositional principle, portraits were gleaned from a variety of published summary sources (Coates, 1989; Edwards, 1989; Jaxtheimer, 1982; Petersen and Wilson, 1978; Schneider, 1994; Wilson, 1979). 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 portraits were selected as the first portrait by a given artist in each source 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. (This sample was concentrated on the 15–19th centuries, whereas that in Tyler, 1998, had a higher representation from the 20th century.)

In the database of paintings, one of the sitter's eyes was centered in an approximately Gaussian distribution with a standard deviation of only $\pm 5.2\%$ of the frame width (Fig. 5). The distribution is remarkably narrow, considering the latitude given to artists in capturing the spirit of their subject, and considering the perennial push to develop new techniques and styles. The single-eye distribution was narrower than that for the halfway point between the eyes (which had a bimodal form), implying that one eye was significantly more centered than the two eyes as a whole (see Fig. 6). This comparison suggests that it is really the individual eye that dominates the geometry, even though virtually every human has two eyes that are jointly expressive of the individuals' thought processes and feelings.

The histograms of Fig. 5 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 7 and 8) 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 for viewers 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 (beginning with Alberti, 1435 and including Ruskin, 1877–1879; Henri, 1923; Goldwater and Treves, 1945; Arnheim, 1954, 1988; Gombrich, 1969; Jaxtheimer, 1982; Kubovy, 1986; Edwards, 1989; Kent, 1995; Dunn, 1995 and Puttfarken, 2000). The first mention of the eye-centering principle in portraits, which has been a common practice for six centuries, seems to have been by Helen van Wyk (2001).

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 (Igel

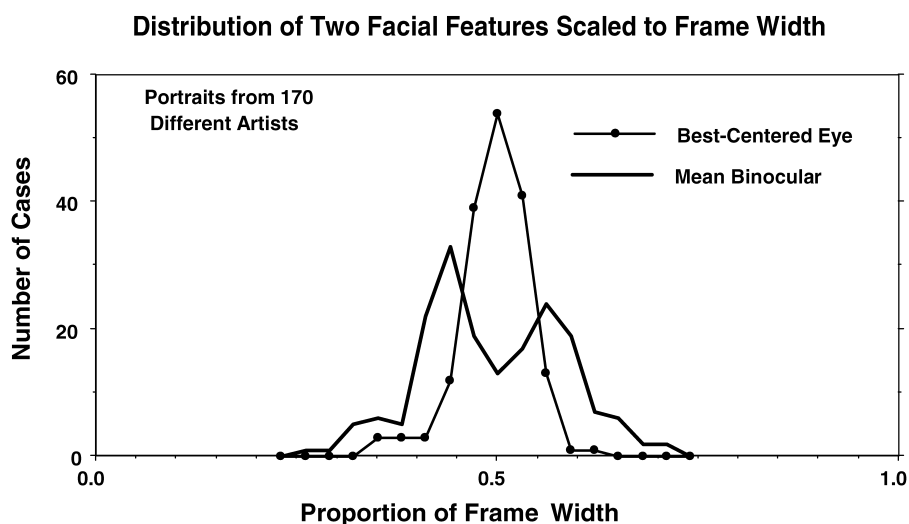


Figure 5. Histograms of lateral location of the best-centered eye (filled symbols) compared with the mean binocular position in portraits from 1400 to 1900. The position of an eye was defined as the position of the center of the eye opening, regardless of the location of the pupil. Note the narrowness 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 squared 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.

Figure 6. (See color plate VI) Eye strips for a sequential series of 21 classical portraits from Schneider's (1994) 'The Portrait' provide a visual depiction of the eye placement. Each strip includes the full width of the painting from which it came, with a range of about 2:1 in width over the set of paintings; the widths were all normalized to the same value to provide an evaluation in terms of frame geometry. Note that about 2/3 of the eyes have one of the pair positioned within the range of $\pm 5\%$ of the distribution (white lines), which is about one eye width.

and Harvey, 1991), based on the conceptualization of Arnheim (1954) depicted in Fig. 1. 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 (Igel and Harvey, 1991). Since the design of a portrait involves the positioning of many entities in the frame, the latter value should be the relevant comparison. It therefore seems that the intuitive (or unexpressed) placement of the eye in artistic portraits is about as precise as the attentive performance of those who were focusing on positioning as their sole perceptual task.

Having analyzed the lateral distribution, the present 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

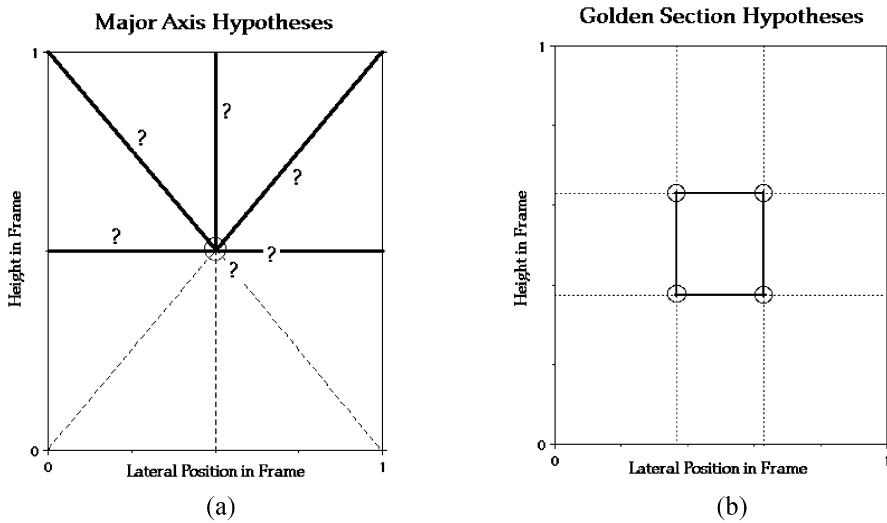


Figure 7. (See also color plate VII) Classic compositional principles for positioning figure elements with respect to the frame, and empirical feature distributions in portraits. (a) Major cardinal and diagonal axes of the frame, intersecting at the geometrical centre. (b) The four Golden Section lines, forming a Golden Rectangle at the centre. (c) Two-dimensional histogram of position of most-centered eye in portraits (defined as for Fig. 5). (d) Two-dimensional histogram of position of mouth in portraits. Rose-colored lines indicate center vertical and upper Golden Section, which intersect close to the center of the eye positions in c. The mouth distribution is scattered more broadly around the geometric center of the frame. The mouth distribution cannot therefore account for the tight distribution of eye positions.

of the face. Before performing the empirical analysis of mouth position as a comparison, it is instructive to depict potential hypotheses for compositional elements such as the position of a feature on the basis of the explicit analytic framework of artistic composition. One such compositional tool is the major axes of the frame shown in Fig. 7a, according to which a feature might be expected to be positioned in the frame. Of course, the dominant focus here is the exact center of the frame, generating the competing hypotheses that either a feature or the center of symmetry (in the case of the two eyes) should be tightly distributed around the center of the frame (Arnheim, 1988). The most important of the four axes is the vertical, so another hypothesis is that a feature 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. 7a, this elaboration might be hypothesized to lead to the tendency to position a feature close to one of the diagonals in the frame, or along the horizontal center line. Which of these various cardinal lines would control the eye distribution?

In this context, the two-dimensional placement of the most-centered eye may be compared with that of the mouths in the same set of portraits. Two-dimensional gray-scale histograms of these two features (Fig. 7c, d) show three properties: 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.

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 an empty space above the head when a lot of the body is 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. An alternative 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, or patrons. An example is the famous picture of the Infanta Margarita by Diego Velazquez, where the head of the Infanta is set 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 their eye position principles, which will be structured in terms of the positions of both eyes, in order to remove the small narrowing of the distribution laterally that occurs when choosing the most-centered eye.

In addition to the general positioning principles of Figs 7 and 8, 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 in portraits, the result would tend to be a centering of the eyes for portraits in frontal view. Moreover, 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, necessarily involves scaling the distance between the eyes proportionately downward. 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. 8a). 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.

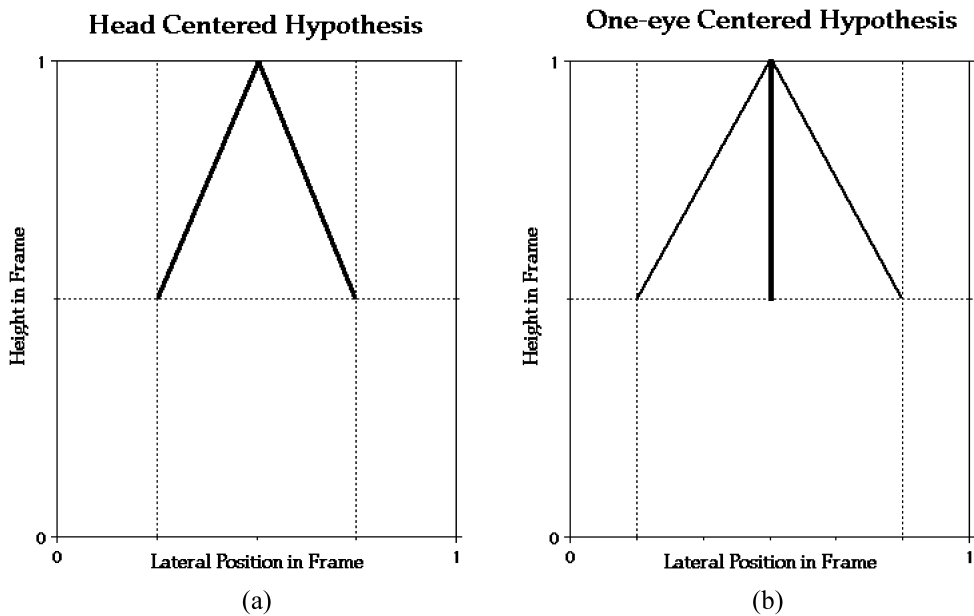


Figure 8. Two-dimensional distributions in single-figure studies, allowing a wider range of head sizes. (a) On the head-centered hypothesis, eye-position loci form an inverted V-shape on the assumption that head is placed near top of picture. The width of configuration goes to maximum when the face fills the frame, assuming that the eyes are halfway down the head. (b) The eye-centering hypothesis predicts a 'tripod arrowhead' configuration of eye-position loci on the same assumption. If one eye is centered, the head must be situated to the right or left, allowing a somewhat broader base to the distribution.

The final compositional principle, shown in Fig. 8b, is that one eye is centered on the vertical 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 with a central vertical, forming an inverted tripod shape.

There are thus a dozen or more hypotheses that could be drawn from current art analysis as the scaled positioning of eyes in single-figure studies, in addition to the null hypothesis that there is such a wide 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. 8c. 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. 8b rather than the head-centered hypothesis of Fig. 8a. The distributions of the 'other' eyes (either to the left or to the right in Fig. 8c) fall near the oblique lines of the 'arrowhead' configuration. 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.

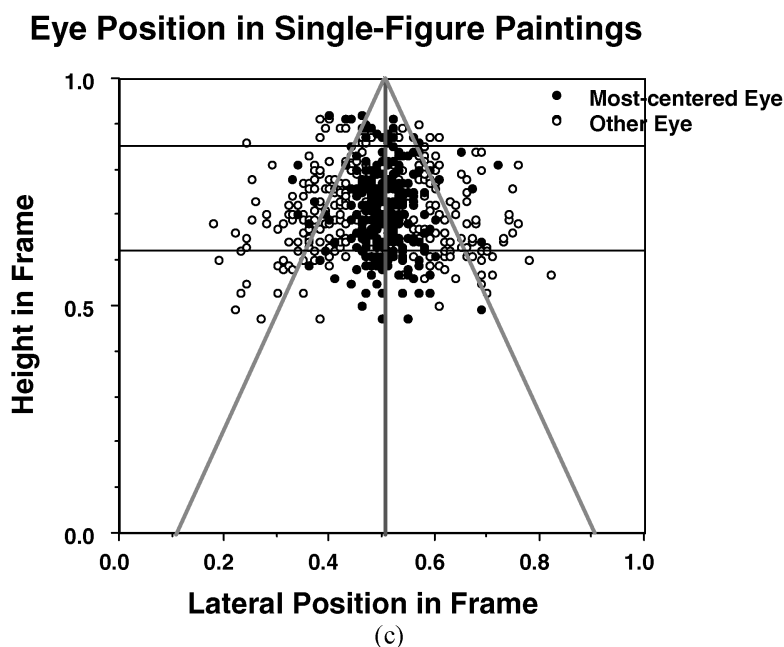


Figure 8. (Continued.) (c) Two-dimensional positions of eyes single-figure studies from 282 different artists over the past 600 years. The figure studies were selected according to the same principles as the portraits of Fig. 5, except that all figure lengths were included. The proportions of all paintings were normalized 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. Virtually all the eyes were located above the center, excluding the centering geometry of Fig. 7a as the organizing principle. However, except for a 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 of Fig. 7a or the Golden Section square of Fig. 7b seem to account for any of the eye placements. The positioning of all eyes matches the arrowhead pattern of the scaled centering of one eye on the center vertical 8b, rather than the inverted V-shape of the head-centering principle 8a.

A possible role of the Golden Section principle is depicted by the horizontal 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 horizontal line represents the Golden Section of the upper rectangle defined by the lower horizontal 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 approximate quarter of the height range lying between the Golden Section and Golden Subsection levels.

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 of either the eyes or the heads at the center of the canvas (Arnheim, 1988). The vertically displaced centering that is evident in Fig. 5c is reminiscent of the peak of the distribution of initial eye fixation positions in a study of free-viewing of scenic images (Mannan *et al.*, 1995). From the examples given in that study, the images did not appear to have a dominant focal element at the peak fixation 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 study. It is noteworthy that the centered location of both the eye in portraits and the initial eye fixations matches the location of the apex of the compositional pyramid (Fig. 2). This coincident location brings an extra factor to the compositional pyramid, which is not usually conceptualized as having any special significance to its apex. Indeed, the composition of portraits is often itself pyramidal, with the shoulders and the arms forming the sides of the pyramid converging on the centered eye (see Figs 10 and 12).

A TEST OF THE EYE-CENTERING PRINCIPLE IN AN INDEPENDENT ARTISTIC TRADITION

How general is the phenomenon of eye centering in portraits? In one sense, Western European art may be considered to belong to an integrated school of continuous interrelation between the artists, from master to pupil, through the centuries. Once art academies and museums were set up, artists could go and imbibe the styles of their forebears, providing a subconscious transference of effective design principles even if they were not discussed specifically or committed to print. In this context, it is exciting that an epoch of portraiture has recently been uncovered that is quite remote from the Western Renaissance tradition. These are the Fayyum funerary portraits of the expatriate Greeks in Egypt, in the first and second centuries AD. Arising from a vibrant intellectual community in Egypt that included many converts from the Roman repression of the Jews, these portraits have an astonishing freshness of technique and vivid sense of the subject depicted. They have been largely ignored until recently because they were from an outpost of the Roman Empire and seemed provincial with respect to the centers of Greek culture, but did not qualify as Egyptian art from their country of origin because they were painted by expatriate Greeks.

The Fayyum portraits were painted as a substitute for the carved death masks in the mummification practice that was adopted from the Egyptian culture by these

indigenous Greeks. The portraits were painted rapidly in encaustic (wax paint), but seem to have been done long before the death of the subject, since most of them show the subject in the prime of life. The artists were evidently able to employ a full range of the tools of the realism so prized during the Renaissance, including foreshortening, shape-from-shading (known to artists as *chiarascuro*), reflective highlights, cast shadows, subtle color gradations, and so on. The portraits were wrapped in place with the elaborate burial shrouds, forming a defined frame around the face against which the eye position can be judged. As can be seen in the four examples reproduced in Fig. 9, in many cases the head is actually decentered such that one eye is positioned quite close to the center of the aperture of the shroud. In (Fig. 9c, d) the heads are even frontal, so there is no compositional reason to disturb the symmetry of a central placement (other than an eye-centering tendency). This asymmetry contrasts strikingly with the carved death masks of the Egyptians, which are always completely symmetric. Although not all Fayyum portraits are as decentered as these examples, it is particularly interesting that the head is often shifted away from centered location in the frame, as though it were more important to bring one eye close to the center than to follow the oft-cited principle of centering the mass of the head. Clearly, the practices of this remote community of portrait artists conforms to many of the same principles as much of later Western art, which seems to have developed in complete ignorance of their forebears.

EYE-CENTERING BY PARTICULAR ARTISTS

Although the general survey of eye-centering in Figs 5–8 took a single randomly selected example from each of the artists available in the survey, it is instructive to focus on a few artists to look at their particular use of the centering principle of compelling portraits. It should be emphasized that even if there is such a principle in operation in portraits in general, it may be used by particular artists in different ways on a variety of occasions. An artist may wish to depict a particular individual as indolent or disinterested by avoiding the centered location. They may wish to distinguish themselves from their fellow artists by typically using some other location, or by pushing the eyes towards the edge of the canvas to create an impression of entrance, or exit, or by emphasizing the facial symmetry with a symmetrical placement, and so on. With these possibilities in mind, we examine the works of one classical and three modern artists. Where the full distribution does not straightforwardly match the narrow Gaussian of the overall artist sample, simple criteria are sought to isolate part of the artist's corpus that may match this principle, where the remainder may violate it in some way. This process emphasizes that, particularly for more recent artists, the eye-centering principle may be either used or violated in service of the particular purpose of the artist in particular circumstances.

The classical artist, Rembrandt van Rijn (1606–1669), is renowned for the variety and emotional depth of his self-portraits. He is recognized as having painted more

than fifty self-portraits, forming a complete corpus that has been analyzed from many angles. Three examples are shown in Fig. 10.

Figure 11 provides a graph of the most-centered eye from all the Rembrandt self-portraits (White and Buvelot, 1999), together with the best-fitting Gaussian function, which has $\sigma = \pm 5.3\%$ of the frame width. This function is clearly an excellent fit to the measured data, and fully validates the idea that the most-centered eye is accurately centered with a narrow distribution. On the one hand, Rembrandt is often viewed as one of the most classical of artists; on the other hand, his adherence to the centering principle is perhaps surprising because he is known for his looseness of style and exploration of varieties of dress and emotional range, particularly in his self-portraits.

Coming forward in time, we may push the envelope of the centering concepts by considering three artists who 'broke the rules' of portraiture in characteristic ways: Amedeo Modigliani, Pablo Picasso and Francis Bacon. An example in each of their styles is shown in Fig. 12. Modigliani (1884–1920) had a somewhat romantic style, but is known for his keen observation of, and exaggeration of, the asymmetry of faces. In comparing his works with those of other artists, it was noteworthy that he departed from the standard style in many cases to paint extreme close-ups, which tend *a fortiori* to center the face (rather than one eye) in the picture frame. These paintings are therefore treated as a distinct genre and analyzed separately, on the criterion of the head outline being greater than 0.5 of the picture width.

Thus, the standard-format portraits of Modigliani were fitted by the Gaussian function and found to show centered distribution with a spread of $\sigma = \pm 6.8\%$, similar to the standard case. As expected, the close-ups did show a significantly different distribution (dashed function), with its peak skewed from centering by about 0.1 of the picture width. Note that the distribution for eye-separation > 0.5 is not bimodal, as would be expected if the head were being centered with a random inaccuracy of placement, but is almost exclusively right-biased.

The next artist, Picasso (1881–1973), was renowned for breaking almost all the rules of painting, particularly the representational rules of the organization of the features in the face of his subjects. One of the principal inventors of Cubism, Picasso broke many rules of realism, perspective, stable viewpoint, color and form. It is therefore of interest to find that the majority of his portraits, despite their use of a wild vocabulary of feature gadgets, maintain as tight a localization of the most

Figure 9. (See color plate VIII) Four portraits from the Fayyum period of ancient Egypt, illustrating many of the same artistic properties as the classical portraits of later millennia, including the proximity of one eye to the center vertical. Note that the head is not centered in the very limited aperture of the mummy case, implying more freedom in head placement than is often supposed. (a), (b) These two heads are turned, but the faces and even the hair outlines are also decentered. (c), (d) The two faces are almost frontal but are notably decentered for no obvious compositional reason.

Figure 10. (See color plate VIII) Three Rembrandt self-portraits. Note the tendency to eye centering despite the compositional asymmetries.

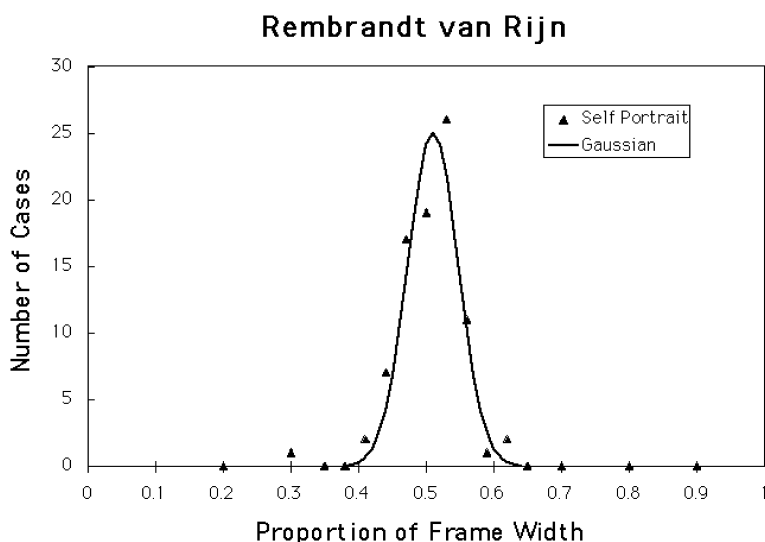


Figure 11. Location of the most-centered eye in all 57 of Rembrandt's self-portraits, from 'Rembrandt by Himself' by Christopher White and Quentin Buvelot (1999).

Figure 12. (See color plate VIII) Examples of portraits by (a) Modigliani ('Portrait of Jeanne Hebuterne', 1919), (b) Picasso ('Portrait of a Man Writing', 1971) and (c) Bacon ('Study for a Portrait of a Pope, VI', 1961).

centered eye as the classical portraits of the previous centuries. For the present sample, the distribution has $\sigma = \pm 5.5\%$, about as narrow as any of the distributions measured to date. The tails of this narrowly-centered distribution also have a few outliers from that presumably represent various iconoclastic experiments.

The final artist that to be considered is Francis Bacon (1909–1992), one of the dominant portraitists of the second half of the twentieth century. Bacon took Picasso's iconoclasm a step further, often reducing his sitter's physiognomies to visceral smudges (with, however, profound emotional effect). His backgrounds nevertheless betrayed a serious obeisance to classicism, often laying out a well-defined space and even introducing a perspective 'box' to contain the visceral apparition of his subjects. Despite their extreme distortion, the portraits usually have at least one well-defined eye, allowing its positioning to be assessed. However, Bacon departs from the single-panel format of most portraits to paint many sets in triptych format. Since the side panels of triptychs often have a subsidiary or accompanying role to the central panel, it was felt necessary to exclude them from the analysis. As with Modigliani, a substantial proportion of Bacon's portraits were close-ups (defined as the head occupying more than 50% of the frame width), which were analyzed separately because the limits of the picture frame add extra constraints to the possible head and eye placements. The result, shown in Fig. 15, is to reveal that the individual portraits and center panels of triptychs again adhere

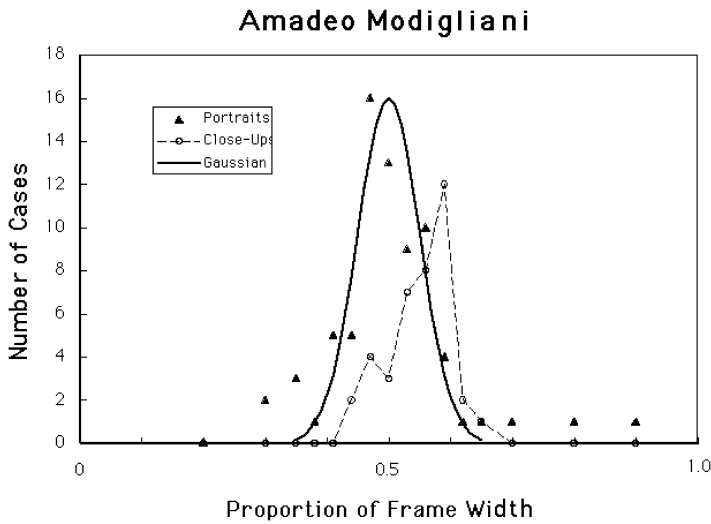


Figure 13. Analysis of the portraits of Amadeo Modigliani. From ‘Modigliani’ by Christian Parisot (1992) (based on measurements of all the single-figure waist-up portraits — full line). Portraits in which the head filled more than 50% of the frame width are analyzed separately — dashed line.

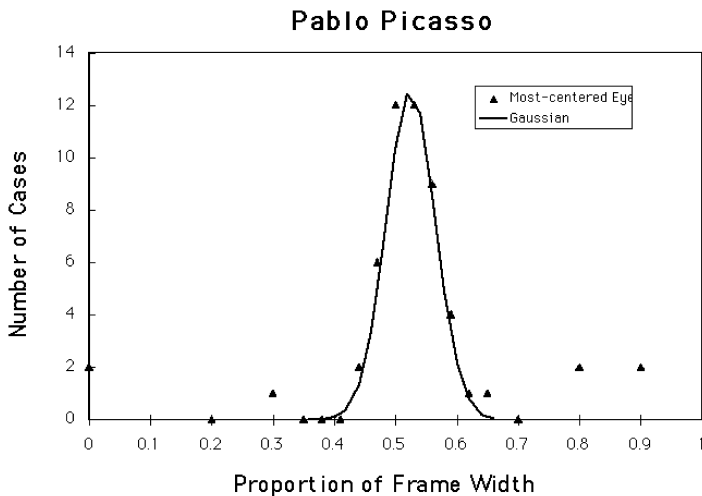


Figure 14. Analysis of the portraits of Pablo Picasso (based on measurements of all the single-figure waist-up portraits from ‘Picasso and Portraiture’ by William Rubin, 1996).

closely to the eye-centering principle, with a similar distribution to the other examples ($\sigma = \pm 5.6\%$).

The distribution of most-centered eyes in the close-ups, on the other hand, is strongly biphasic, with peaks at 0.41 and 0.62 picture widths. This is the form of distribution expected if the heads are centered symmetrically in the frame in roughly frontal view. It is important to note that division of the sample of Bacon portraits on the basis of head size (relative to the frame) reveals two different principles in

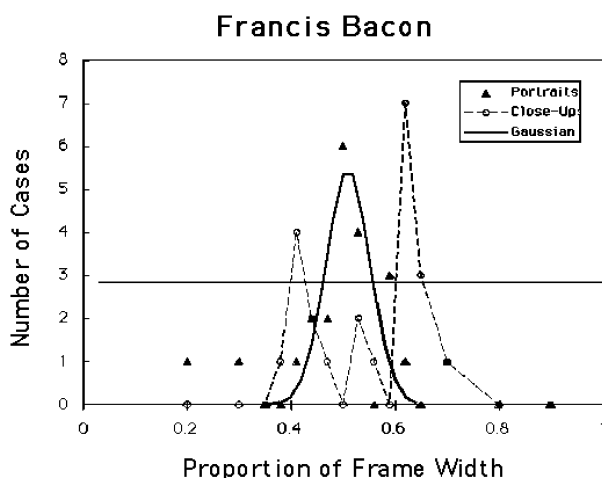


Figure 15. Analysis of the portraits of Francis Bacon, in the same format as Fig. 13 (based on measurements of portraits from ‘Bacon: Portraits and Self-Portraits’ by Francis Bacon, France Borel and Milan Kundera, 1997). Note standard format for generic portraits, but double-peaked distribution for close-ups.

operation. The symmetry solution is evidently rare in the history of portraiture, since it is not evident in the full sample of Fig. 8. However, it is something that has been occasionally used in the past, and which Bacon evidently employs extensively. The two principles (eye-centering and head-symmetry) may be regarded as local energy wells in the configurational space of aesthetic choices of composition. There must be many more such principles to discover. Such quantitative analysis should be able to reveal the configurational landscape of pictorial compositions that have been employed by thousands of artists over the centuries.

CONCLUSION

In summary, the operation of compositional principles in paintings of various types is a fundamental aspect of their artistic appeal. These principles can be studied by controlled scientific experiments, but the alternative approach of the present work is to use the wealth of art works as a database for direct analysis. This paper focuses on the genre of portraiture as a vehicle for the exploration of compositional principles in relation to the canvas frame. 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 two-dimensional center of symmetry, which is the explicit organizing feature in many analyses of portrait technique, plays only a minor role in the composition. That explicit compositional principles are implemented with an unbiased accuracy of the order 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 largely intuitive or subconscious to the artists themselves suggests that hidden principles are operating in our aesthetic

judgments (perhaps in many realms beyond the portraiture that is the topic of the present empirical study). The details of the analyses make clear that the eye-centering principle is only one of many operating in portrait composition, and in pictorial composition in general. Indeed, it may be integrally related with the compositional pyramid that has been a well-established principle of composition since the Renaissance, with the eye falling near the apex of a pyramid defined by the arrangement of the sitter's arms and shoulders.

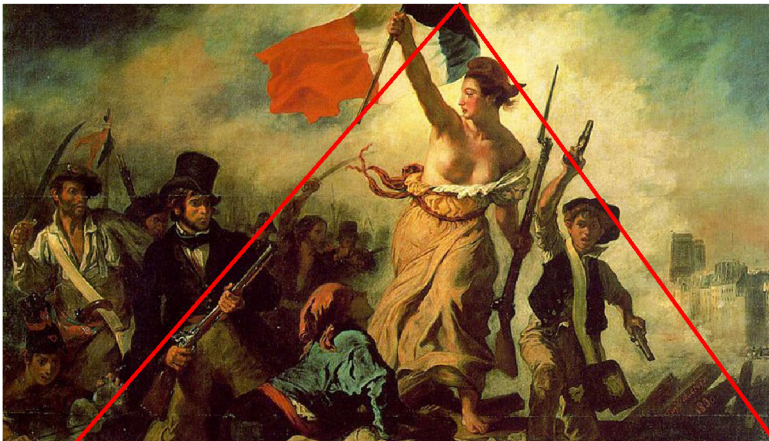
Nevertheless, the centered eye should not be taken as an obligatory principle for portrait design, but a power locus that can be used to generate the sense of a penetrating consciousness in the sitter, if this is the artist's intent. It is noteworthy that the rest of the portrait typically follows the dominant precept in painting, which is to avoid a symmetry of composition often characterized as being boring. It seems that the interplay between the overall asymmetry of most compositional elements and their arrangement around the fulcrum of the midline eye location generates a strong aesthetic effect. However, analysis of this asymmetric/symmetric combination has resisted quantification because specifying its degree of asymmetry or the interplay of its perceptual forces has not proved practicable.

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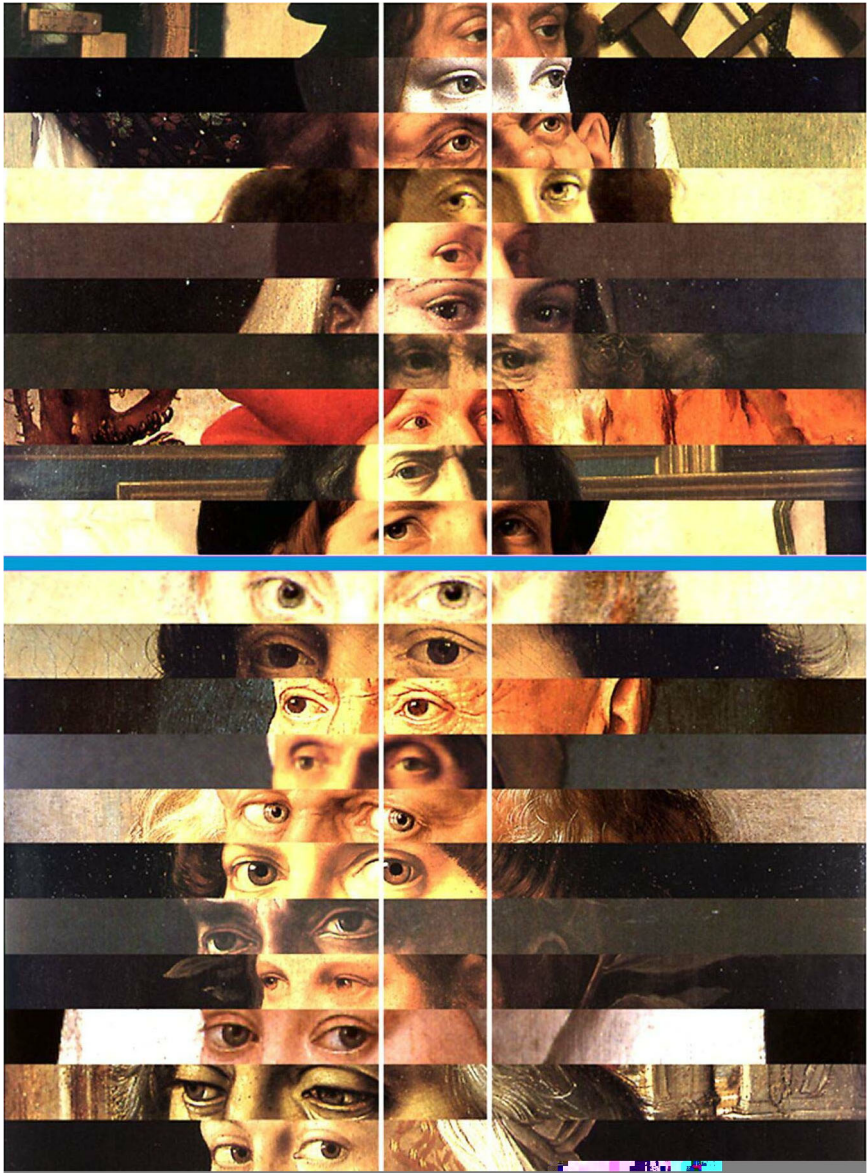
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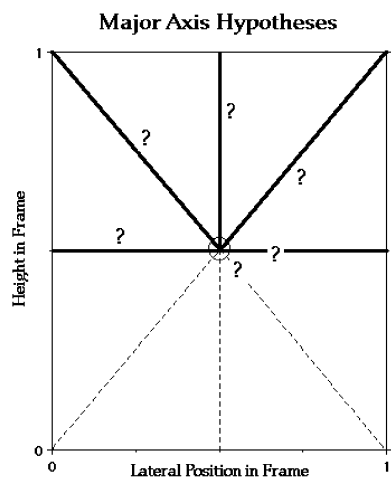
Plate V



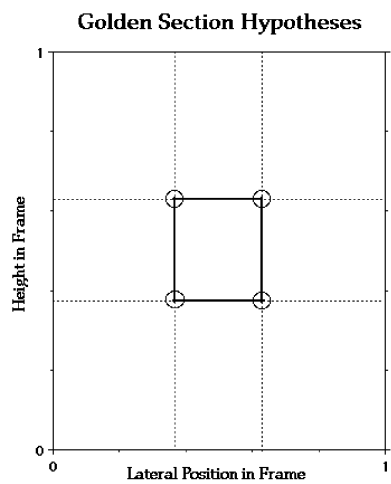
C. Tyler, Figure 2.



C. Tyler, Figure 6.

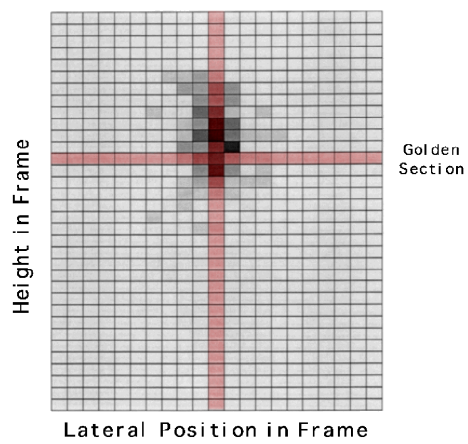


(a)



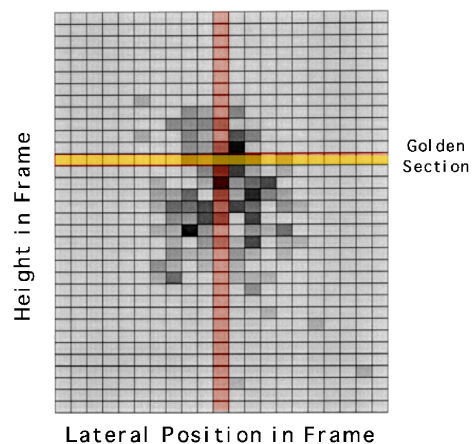
(b)

Position of Most-Centered Eye



(c)

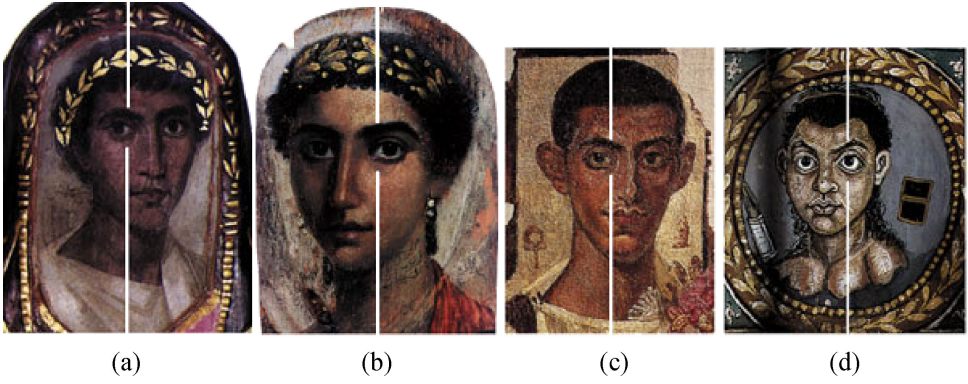
Position of Mouth



(d)

C. Tyler, Figure 7.

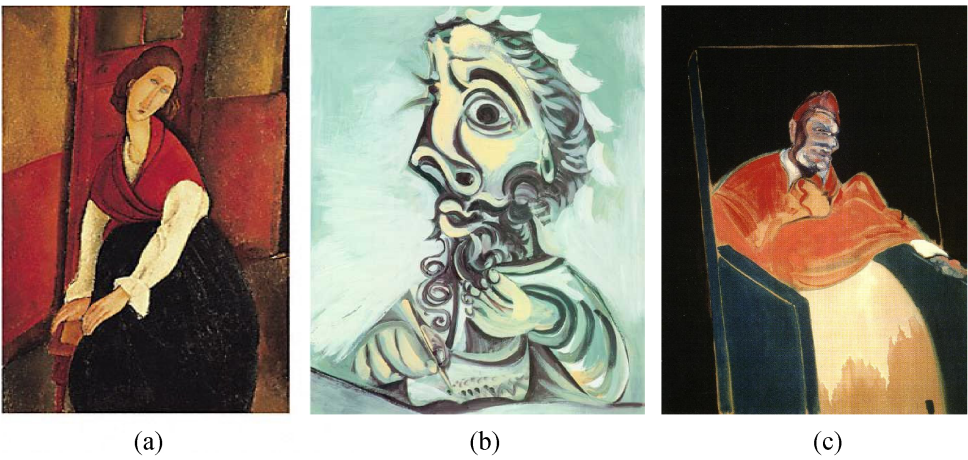
Plate VIII



C. Tyler, Figure 9.



C. Tyler, Figure 10.



C. Tyler, Figure 12.