
The Golden Section: Elusive, but Detectable

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ABSTRACT: The relative significance of the “golden section” ($\cong 0.618$) and other notable proportions was investigated using a new unobtrusive methodology, a modified Fechnerian method of production. Fourteen professional painters each sketched under controlled conditions—“veridically, accurately, and realistically” (but without there being any mention of proportions)—27 complex stimuli presented as slides, thus producing a total of 378 sketches. The stimuli in the slides were (a) vase cutouts of various proportions placed in a mantelpiece context and (b) paintings by Kodama, Mondrian, and Whistler. The golden section and other significant and control proportions (a total of 120 occurrences) were identified beforehand by the researcher in the 27 stimuli. The 378 painters’ sketches were subsequently measured by the researcher and two assistants to determine the accuracy with which the various proportions had been reproduced by the painters (a grand total of $1680 = 14 \times 120$ —possible occurrences). The overall accuracy of rendering the proportions was found to be low for the vases and Kodama’s paintings, but increased considerably for the Whistlers and Mondrians. As predicted, the accuracy of rendering the golden section increased from the vases to the Kodamas to the Whistlers and Mondrians. For the latter two, the golden section was in fact the most accurately rendered proportion, followed by 1.00 (found, for example, in the square and circle). The golden section is clearly important in art and to artists, but both its use and detection are subtle and must be pursued with great analytic care. The use of professional artists as informants and research participants may be of considerable help.

The golden section (or $\phi' \cong 0.618$; phi is for the Greek sculptor and architect Phidias) is a proportion that has in its various geometric, arithmetic, biological,

architectural, and artistic contexts fascinated, for over 2000 years, some of the finest minds in philosophy, the sciences, and the arts. It has been considered the epitome of beauty by aestheticians, such as Baumgarten (1961/1750–1758) and Zeising (1854, 1855, 1884–posthum.). In the 20th century, Huntley (1970) used it as a major example of aesthetics in mathematics, Bouleau (1963) identified it in major Western paintings, and Le Corbusier (1954) made it the building block of his *Modulor*—the proposal for a fusion of the functional and the aesthetic in architecture (see also Arnheim, 1966).

The Leipzig psychophysicist Gustav Fechner (1871, 1997/1876) performed the seminal experiments on the preference for the golden section in rectangles. These experiments, important as they were in representing the beginning of modern empirical aesthetics (the so-called aesthetics from below), proved perhaps too influential. Countless researchers, mostly psychologists, have since attempted to examine the significance of the golden section more or less rigorously (see Green, 1995, and Höge, 1995, for extensive reviews). But much of the research (dubbed “rectanglyphics” by a wit) followed Fechner’s work too closely, in that an insufficiently broad sampling of research problems, stimuli, contexts, and types of participants was used.

The problem nevertheless continues to fascinate researchers from several scholarly disciplines, as is

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evident from a recent special issue, with H. Höge as guest editor, of the journal *Empirical Studies of the Arts (ESA)*, which was devoted entirely to the golden section (1997). However, several articles in the issue came to sharply negative conclusions about any special significance of the golden section (compared to other proportions), as well as about the general viability of the golden-section hypothesis (e.g., Boselie, 1997; Shortess, Clarke, & Shannon, 1997), leading Höge (1997) to talk of that *ESA* issue as the occasion of the golden section's "last funeral" (he did add a question mark).

In a series of three experiments reported in the same issue of *ESA* (Konečni, 1997), I used several classical psychoaesthetic methods introduced by Fechner (production, choice/preference) and a variety of stimuli and tasks (line bisection, production of rectangles, preference for vases of different proportions), all of which were embedded in contexts that systematically varied in aesthetic relevance (e.g., placement of a vase of given proportions on a mantelpiece of a given length). It was found that the research participants (university students), when working with elementary stimuli and tasks (line bisection, rectangle production, etc.), showed no preference for the golden section, no matter how the questions were experimentally posed to them, and even when the degree of ecological validity (aesthetic significance) of the tasks was considerable.

In one of the experiments, however, the participants were given the choice of 11 vases, 5 of which had golden-section proportions; the 6 others had theoretically significant non-golden-section proportions (0.50, 0.67, 0.75). The striking result here was that almost half of the participants chose one vase—from the golden-section series (see Konečni, 1997, Table 7 and Figure 5), which occurred despite there being no general preference for the golden-section vases.

Several conclusions, relevant for subsequent research, could be drawn from these and related results. The facts that the golden section is elegantly demonstrated in the geometry of lines and rectangles, and psychology's historical predilection to mimic the 18th-century physics uncritically and to reduce (the irreducible?) phenomena to meaningless constituents, ignoring context, have both contributed to leading the psychoaesthetic research on the golden section into a seemingly blind alley.

Moreover, the simple introduction of aesthetic relevance, such as using the golden section as the basis of

the shape of an aesthetic object (e.g., a vase), does not guarantee its appeal. Rather, as the strong preference for a particular golden-section vase indicates, in a task with manifold features, perhaps the golden section does play an important role, not as a main effect or in collaboration with a single contextual variable, but as an essential contributor to the higher order interactions (perhaps with color, size, structure, composition), which govern preference and choice in the real world of aesthetics and art.

A further consideration is the choice of research participants. In the psychology of music, for example, there has been a lively discussion of the implications of using novices, as opposed to experts (e.g., Konečni & Karno, 1994; Swain, 1994), but this has been far less the case in the psychoaesthetics of visual art (but see Konečni, 1991; Nodine, Locher, & Krupinski, 1993), and specifically in the work on the golden section (cf. Macrosson & Strachan, 1997). The negligent overreliance on nonexperts can perhaps be traced to Fechner's confounding the empirical, anti-Kantian, "aesthetics from below" with the use of "participants from below." In fact, the golden section can be considered a prime example of a concept in the art and architecture that has been transmitted through the creating and consuming (especially European) elites. It may simply not be possible to investigate the golden section properly with lay participants, because, even though elite aesthetic judgments may significantly affect public space, they may not overwhelm the public taste. "Even if... the golden section [was used] on the Parthenon, and the Athenians loved it, it may not have become noticeable in their taste in vases" (Konečni, 1997, p. 203).

The present research was designed with such considerations in mind and after consulting a number of professional/academic painters (university-level teachers and advanced graduate students in studio art), who were also well-versed in aesthetic theory and methodology. Complex aesthetic stimuli, including authentic paintings, were used. These stimuli contained, as their key structural elements, the golden section and other significant and control proportions. Trained, successful painters (different from those used as informants) served as research participants. A new methodology (accurate sketching of stimuli) was developed—a modified Fechnerian method of production—the aim of which was to unobtrusively tease out the painters' responses to the golden section and other proportions,

without them being aware of the purpose of the research.

Note that, in this research, it is the presence of non-golden-section proportions that constitutes experimental controls; the skills required for the task clearly precluded the use of lay participants as controls.

The main hypothesis was that the golden section—because of its special standing in the arts, and because painters are trained to deal with it and, thus presumably, to detect it—would be attended to more closely and sketched more accurately than the other significant proportions. Furthermore, it was predicted, on the basis of professional painters' input, and again, because of the presumed attentional differences, that the accuracy of rendering all proportions, and especially the golden section, would increase from vases to unknown paintings to famous works. Among the well-known works, the greatest attention was expected to be accorded to those by a painter known and respected for his spatial meticulousness (Mondrian).

Method

Research Participants and Setting

The 14 research participants (4 women, 10 men) were seen individually for about an hour in a large, comfortable room in the author's psychoaesthetic laboratory suite at the University of California, San Diego (UCSD). They were professional painters, faculty, and graduate students in studio art (Mdn age = 29.5, $M = 31.7$, range 24–50 years), who were recruited in various ways in the San Diego and Orange Counties arts community for a "laboratory study of sketching." All had a minimum of 7 years of formal art training and practice (Mdn of training + practice = 11 years, range 7–33 years).

Stimuli, Instructions, Procedure

A warm-up stimulus (a color photograph of a coil of rope on a dock) and the 27 experimental stimuli were presented as standard slides, which were projected onto a white wall that was located about 435 cm in front of the seated participant. The size of the image on the screen was 66 × 99 cm.

Sixteen of the stimuli were four black cutouts of vases, each of which was photographed in color at one of four positions on a beige mantelpiece. The vases

were nos. 2, 4, 7, and 9 from the author's earlier experiments (Konečni, 1997, Table 1, p. 180). Vases nos. 2 and 4 incorporated in their design two golden-section proportions each; nos. 7 and 9 incorporated two 0.50 proportions each (see the 1997 paper for details). The four locations on the mantelpiece—implying four different line bisections—were: 0.50 (midpoint), 0.62 (golden section), 0.70 (control), and 0.75 (a proportion that is, like 0.50, considered significant in psychoaesthetics), with the left-right positioning counterbalanced (see Figures 5 and 6 in Konečni, 1997, for the appearance, respectively, of vase no. 2 at the left golden-section point of the mantelpiece and vase no. 9 at midpoint). The preceding information is summarized in the top part of Table 1. As an example, for vase no. 4, placed at 0.50 (midpoint) of the mantelpiece, one 0.50 and two 0.62 CPs are indicated.

Seven of the stimuli were color photographs of original semiabstract and abstract paintings by Robert Kodama, a young, relatively unknown painter who had incorporated the golden section into his paintings both prior to having formal knowledge of the concept and intentionally after learning about it (by taking a "psychology and the arts" class from me at UCSD). Information regarding the presence of the golden sections and other proportions—"criterion proportions" (CPs)—in each of the seven paintings is presented in the middle section of Table 1.

A word is in order about the selection of the CPs. In principle, in the case of most paintings, including the abstract ones, one can identify a very large number of relationships that can be expressed as proportions. In the author's work (e.g., Konečni, 2001), including this study, the choice of CPs is very carefully made from a large pool of detectable proportions with as little arbitrariness as possible. A laboratory research team, which includes professional painters, discusses each painting that is a candidate for inclusion. Then, only major and obvious structural and compositional elements on which there is general agreement are included among the CPs. Some of the elements that are likely to be included are the vertical (left-right) bisection of the painting; the horizontal (top-bottom) bisection; the key facial and bodily proportions of the major human figures; the dimensions of the most prominent depicted objects, such as houses, bridges, windows, crosses, or vases; and the major compositional relationships, including the spatial arrangement of color. The overall dimensions of the painting can also be included among

Table 1. Criterion Proportions Present in Vases and Paintings Stimuli

Stimuli	Placement ^a	Number of Criterion Proportions Present						
		0.50	0.62	0.67	0.70	0.75	1.00 ^b	Other ^c
Vase ^d 2	0.50	1	2					
Vase 2	0.62		3					
Vase 2	0.70		2		1			
Vase 2	0.75		2			1		
Vase 4	0.50	1	2					
Vase 4	0.62		3					
Vase 4	0.70		2		1			
Vase 4	0.75		2			1		
Vase 7	0.50	3						
Vase 7	0.62	2	1					
Vase 7	0.70	2			1			
Vase 7	0.75	2				1		
Vase 9	0.50	3						
Vase 9	0.62	2	1					
Vase 9	0.70	2			1			
Vase 9	0.75	2				1		
Kodama I			2		1			2
Kodama II		2	2				1	
Kodama III					1	1		
Kodama IV			3		1			2
Kodama V			2					3
Kodama VI							1	2
Kodama VII		1	2					1
Whistler I ^e			2	1		1		2
Whistler II ^f		3	2		1		1	5
Mondrian I ^g		1	1	2	1	1	1	4
Mondrian II ^h			1	1	4		4	3

^aPlacement = distance of a vase from the left end of the mantelpiece, divided by the entire mantelpiece length (with left right counterbalancing).

^bIn reference to rectangles = square. "Other" criterion proportions were: 0.20 (1), 0.25 (1), 0.30 (2), 0.35 (4), 0.40 (1); 0.45 (1), 0.57 (5), 0.80 (4), 0.85 (3), 0.90 (1), 0.95 (1). ^dVases Nos. 2, 4, 7, and 9 are with reference to Table 1 in Konečni (1997). ^e*Nocturne in blue and gold: Old Battersea Bridge* (1872–1875, 66.6 × 50.2 cm). ^f*Arrangement in flesh colour and black: Portrait of Théodore Duret* (1883, 193.3 × 90.8 cm).

^g*Composition with large blue plane* (1921, 60.5 × 50 cm). ^h*Lozenge composition with red, yellow, and blue* (c. 1925, 101.5 × 101.5).

the CPs, although that was not done in this study for various technical reasons that have something to do with the method of stimulus presentation.

In the bottom section of Table 1 are presented the CPs for the four paintings by James Whistler and Piet Mondrian (also presented as color slides). No writings by and about Whistler emphasize proportions or the golden section; but as is well known, the opposite is the case for Mondrian.

Time constraints precluded the use of a greater number of paintings and painters. The confounding of Mondrian with abstract/geometric style could have been avoided by using in addition his early "figurative" paintings, but this would have only introduced other confoundings such as that of abstraction/geometricity with relative renown.

After signing the consent form, each painter was seated comfortably at a drawing table, on which there was a lamp, charcoal pencils, and a Strathmore 14 × 17 in. (35.56 × 43.18 cm) drawing pad with 80-lb paper. The illumination was reduced in the room to allow good visibility of the details in each slide. The participants were told that they would be presented with a series of slides, each of which would be shown for either 30 or 60 sec (to be announced beforehand), and which they were to sketch as "veridically, accurately, and realistically as possible," while the slide remained on. Prior to each slide being shown, the painters would have 10 sec to prepare. Their attention was drawn to the pages of the drawing pad: On each page a frame with the dimensions of 20 × 30 cm had been drawn. The participants were told that the

proportions of this frame corresponded to the proportions of the image projected on the wall and the request was made to confine each sketch to the area within the frame.

The painters then sketched the warm-up slide for 60 sec (the expiration of 30 sec was also announced, here and in the experiment proper), after which the experimenter answered questions and again stressed the need for accuracy and realism. The 27 experimental stimuli were then shown in a random order (the same for all the participants) for either 30 sec each (16 vase stimuli) or 60 sec each (11 paintings); these time values had been selected through pretesting.

A careful funnel-type interview was then conducted with the participants. The golden section, the issue of proportions, and the differential accuracy with which they may have been captured by the artists were brought up only in the later stages of the interview. The participants' familiarity with Kodama, Mondrian, and Whistler, as well as the topic of intentionality in the use of the golden section and other proportions by artists, was also investigated.

Results

Vases

Only the most pertinent results are presented in this article. Fourteen painters sketched the four vases at each of four mantelpiece locations, thus collectively producing 224 sketches. Because each vase at a particular placement on the mantelpiece yielded three CPs (see the top part of Table 1), there were therefore 672 putative renditions of proportions by the artists: 280 of 0.50, 280 of 0.62, 56 of 0.70, and 56 of 0.75 (see Table 2).

The basic research issue is whether or not the painters were differentially accurate in capturing the proportions presented to them and, specifically,

whether they were relatively more accurate in sketching 0.62 than the other three proportions. An accurate or correct "capture" was defined as a rendition that yielded a proportion within 0.025 on each side of a given CP in the stimulus, thus 0.475–0.525, 0.595–0.645, 0.675–0.725, and 0.725–0.775, respectively. This definition of accuracy has a solid standing in the literature (cf. Höge, 1995; Konečni, 1997).

Overall accuracy in rendering the CPs for the vase stimuli was 137/672 or 20.4%. The main results (summed across all painters and all vases) are presented in Table 2. The $\chi^2(3)$ of 5.69 is not statistically significant ($p < .13$), which indicates that the painters were not more accurate in capturing the golden section than the other three proportions.

Closer inspection of the data underlying those presented in Table 2 indicated that the somewhat more accurate rendering of 0.50 and 0.75 was mostly because the placements of the vases on the mantelpiece at these proportions (compared to the vases' proportions themselves) were more accurately rendered than were the golden-section and 0.70 placements (although, again, this difference was not statistically significant). This explains why Vase 2, overwhelmingly chosen from a set of 11 vases in the earlier research mentioned in the introduction (Konečni, 1997, Experiment 3), did not play much of a role in these results. Yet again, one finds that the preference for the golden section is elusive and contextually dependent.

Kodama

There was a total of 30 CPs in the seven paintings by Robert Kodama (see Table 1), so that the 14 painters, in their 98 sketches of Kodama's works attempted to capture a total of 420 CPs. The results are presented in Table 3.

For these data, $\chi^2(5) = 39.94$, $p < .0001$. This highly significant finding mostly rests on two aspects of the data that are statistically functioning in unison: very low accuracy in response to the 0.70 CPs and very high accuracy in capturing 1.00.

Overall accuracy in rendering the CPs for the Kodama stimuli was 21.9% (92/420), comparable to that for the vases (20.4%). However, the golden section was captured accurately 26.0% of the time, more often than all the proportions in Table 3 other than 1.00. Furthermore, it was captured accurately more often than in the case of vases (see Table 2). This

Table 2. Number and Percent of Accurately and Inaccurately Rendered Criterion Proportions in Vases

Accuracy	Criterion Proportions			
	0.50	0.62	0.70	0.75
Yes	67 (23.9)	50 (17.9)	7 (12.5)	13 (23.2)
No	213 (76.1)	230 (82.1)	49 (87.5)	43 (76.8)

Table 3. Number and Percent of Accurately and Inaccurately Rendered Criterion Proportions in Seven Kodama Paintings

Accuracy	Criterion Proportions					
	0.50	0.62	0.70	0.75	1.00	Other
Yes	7 (16.7)	40 (26.0)	0	3 (21.4)	17 (60.7)	25 (17.9)
No	35 (83.3)	114 (74.0)	42 (100)	11 (78.6)	11 (39.3)	115 (82.1)

Table 4. Number and Percent of Accurately and Inaccurately Rendered Criterion Proportions in Four Whistler and Mondrian Paintings

Accuracy	Criterion Proportions						
	0.50	0.62	0.67	0.70	0.75	1.00	Other
Yes	21	51	22	35	12	48	55
(%)	(37.5)	(60.7)	(39.3)	(41.7)	(42.9)	(57.1)	(28.1)
No	35	33	34	49	16	36	141
(%)	(62.5)	(39.3)	(60.7)	(58.3)	(57.1)	(42.9)	(71.9)

difference in the golden-section capture between the Kodama paintings and the vases (26.0 vs. 17.9%) was statistically significant: $\chi^2(1) = 3.98$, $p = .046$, which is especially noteworthy, in light of the fact that the overall accuracy for Kodama's paintings, as just mentioned, was no higher than the overall accuracy for the vases.

Kodama placed the golden section in five of the seven paintings (see Table 1). In the case of the first three paintings, even though major structural elements were involved, the golden section was used inadvertently, before Kodama was aware of the concept. In the latter two paintings, the golden section was used intentionally. However, the research participants' accuracy in rendering the golden sections in these five paintings did not differ as a function of conscious intent behind their use by Kodama.

There was a total of two 1.00 CPs in the seven Kodama paintings (see Table 1): No less than 17 of the 28 renditions (60.7%) were accurate (see Table 3). This finding in a sense validates the use of the methodology that was developed for this research: Artists, in response to identical instructions, sketched stimuli within artworks with differential accuracy, including high accuracy, which presumably reflected differences in attention to, and respect for, the various aesthetic stimuli, such as vases and paintings.

The two 1.00 CPs were based on a square (three sides of which are present in Kodama II, along with other material) and a circle (present in Kodama VI,

also along with other material). Simple geometric shapes do not guarantee accuracy, however: Kodama III contains an ellipse with the 0.70 CP (along with other material), which was not captured by any of the painters.

Whistler and Mondrian

Fourteen artists collectively produced 56 sketches of the four paintings by James Whistler and Piet Mondrian. As can be seen in Table 1, there was a total of 42 CPs in these paintings. The relative accuracy of capture of a total of 588 CPs was at issue. The results are presented in Table 4. The overall accuracy of capture of CPs was much higher than that for the vases and Kodama's paintings: Across all paintings, painters, and CPs, it was 41.5% (244/588).

The $\chi^2(6)$ of 36.33 is highly significant ($p < .0001$), because, although the other proportions were in the 28.1% to 42.9% accuracy range, the CPs for both the golden section (60.7%) and 1.00 (57.1%) were considerably higher.

It was of interest to compare the capture of the golden section and 1.00 in the four paintings individually. First, consider that the overall accuracy in the individual paintings was as follows: Whistler I, 51.2%; Whistler II, 41.7%; Mondrian I, 26.6%; and Mondrian II, 49.5%. In this accuracy context, in the case of all four paintings, the golden section was the most veridically rendered proportion (71.4, 53.6, 42.9, and 71.4%,

respectively). As can be seen in Table 1, there were no 1.00 CPs in Whistler I, and, in the other three paintings, the accuracy of capturing 1.00 was 42% (one 1.00 CP), 35.7% (one 1.00 CP), and 66.1% (four 1.00 CPs). The painters' relatively high accuracy in rendering 1.00 in Mondrian II was thus heavily weighted.

Earlier, it was shown that the artists captured the golden section significantly more accurately in Kodama's paintings than in vases. There was a considerable further increase in the accuracy of rendering the golden section in the Whistler and Mondrian paintings; a comparison of all three categories of stimuli (golden-section columns in Tables 2–4) yields a highly significant $\chi^2(2)$ of 60.08, $p < .0001$.

Exit Interviews With Participants

Exit interviews with most of the artists were informative. The most pertinent observations for the present report are

1. Only four of the participants were familiar with Kodama and his work. These four artists did not differ from the others in their opinions of Kodama's paintings—some of the descriptors commonly used were “immature,” “talented, but...,” “derivative,” and “shows promise.”

2. All the painters thought that the four Whistler and Mondrian paintings were of exceptional quality, all could attribute the two Mondrians to this painter, all but one attributed Whistler I correctly, and all but four attributed Whistler II correctly (but these four too identified the period and thought the painter would be one of high stature).

3. Although all the painters claimed to have taken all the stimuli seriously, a significant majority indicated, in various ways, that sketching the vases held the least interest for them, and that the impressiveness of the Whistler and Mondrian works had created artistic demands to which they responded with more effort.

4. Almost all the participants thought that they had achieved the highest degree of accuracy in the two Mondrians.

5. No participants spontaneously brought up the issues of the golden section and of the differential sketching accuracy; furthermore, even when prompted, they did not recall noticing or specifically dealing with the golden sections in the vases, Kodamas, and Whistlers; however, although only after the issue had been brought

up, the great majority claimed that they knew of and saw the golden rectangles in the two Mondrians.

Perhaps not surprisingly, some of the above comments echoed those made by the various artists who had been used as informants prior to the initiation of the research.

Discussion

The present research capitalized on the artists' ability to sketch accurately, but also on their predilection to attend more closely to paintings they admire and therefore to achieve greater accuracy in rendering. The artists' latter tendency presumably led to the observable and predictable differences in the display of the former.

The criterion proportions were carefully chosen to involve the key structural features of the stimulus paintings; the golden sections, along with other proportions, had intentionally (Kodama, Mondrian) and unintentionally (Kodama, Whistler) been placed in the paintings by these artists. Under such circumstances, the considerable relative significance of the golden section could be clearly and unobtrusively demonstrated—with a category of participants who had the previously mentioned abilities and predilections. The golden section is important, but subtle and elusive, and its detection could not have been accomplished with lay research participants.

The artists' sketching accuracy did not, however, distinguish between the inadvertently and intentionally used golden sections, although this issue deserves further research scrutiny with a greater range of stimuli.

The expectation that Kodama's major proportions in general would be rendered more accurately than those in the vase stimuli was not fulfilled. However, the more specific prediction that Kodama's golden sections would be more accurately sketched than those present in the vases, and that the highest accuracy of golden-section renditions would be achieved for well-known and admired painters/paintings, proved indeed to be correct. This prediction could not have been made without the input from practicing painters who were also well versed in aesthetic theory.

However, the panel of painters consulted beforehand (as well as the painters/participants) erred in

thinking that Mondrian would be (was) sketched more accurately than Whistler, which was not the case. The golden section was rendered with 71.4% and 53.6% in Whistlers I and II, respectively, which was, if anything, more accurate than was the case for the two Mondrians (42.9% and 71.4%, respectively). Overall, the various Whistler and Mondrian proportions were also rendered with comparable accuracy (44.8% and 39.0%, respectively). These findings are of considerable interest, especially when one considers the dramatic stylistic and thematic differences among the four Whistlers and Mondrians. The findings validate the sketching and measurement methodology developed in this research.

It was earlier suggested that certain aspects of the results came from the greater appreciation that the participants naturally felt for excellent works and that this was responsible for closer attention and greater accuracy. A correlated explanation, of course, is that talented painters have superior compositional skills and therefore use certain proportions in a painting's structure in a way that makes them not just salient, but necessary. They may not, however, succeed in this nor indeed want this in every painting, even within the same stylistic approach: Witness the difference between the sketching accuracy of the two "geometric" Mondrians (26.6% vs. 49.5% overall, 42.9% vs. 71.4% for the golden sections).

The accuracy of rendering any proportion in a sketch very likely depends on its purpose and context within the stimulus painting, but some proportions (e.g., 0.62, 1.00) may habitually be more closely attended to by painters/participants or else generally may be given a more prominent and salient role by the paintings' creators. The method by which the present stimuli were chosen for inclusion in the experiment, however, favors the former explanation: The golden sections in the vases were matched by other significant proportions and the paintings were definitely not chosen to emphasize the golden section or exclude the competing proportions.

A few words are in order about 0.62 versus 1.00. In the case of Kodama's paintings, the golden sections, although being rendered more accurately than all the other CPs—were sketched considerably less accurately than the two 1.00 proportions (derived from an incomplete square and perpendicular diameters of a circle). In the case of the Whistlers and Mondrians, however, the accuracy of rendering the two proportions was

comparable overall (and high, around 60%), but the golden section was the most accurately sketched proportion in all four paintings; 1.00 benefited from multiple appearances of the same geometric shapes in Mondrian II. In this research, 0.62 versus 1.00 looks like a draw.

The circle and the square are perfect forms that are salient and relatively easy to sketch accurately (within the margin of error allowed in the present research). The golden section—as it is present, for example, in the golden rectangle (and especially an incomplete golden rectangle that is found in Mondrian II)—is far more difficult to sketch accurately, but presumably poses a welcome challenge to a skilled and informed artist. It is a subtle proportion, the attractiveness of which perhaps depends on its fine balancing act between boring or extreme values (between 0.50 and 0.67, with regard to $\phi' = 0.62$; between 1.00 and 2.00, i.e., equality and doubling, with regard to $\phi = 1.62$; cf. Arnheim, 1966; Berlyne, 1971; McManus & Weatherby, 1997).

If the boring, frequently occurring proportions such as 1.00 were regarded as prototypes even in classical Greece, the golden section may have originally acquired appeal because it introduced a pleasing degree of imbalance, unfamiliarity, complexity, and tension. Perhaps it was too successful in this role in the arts (cf. Bouleau, 1963) and thus itself became a prototype.

A final word about what might have motivated or determined or induced the painters to do what they did—depending on one's favorite psychological theory: Whereas it is tempting to impute the painters' differential accuracy to their intuition, to their immediate perception of aesthetic quality, or to their use of quick and simple heuristics, the data do not really bear out any of these ideas. As is the case with so much of my work on the golden section, these findings suggest that none of the one- or two-factor theories are at work and that higher order interactions are at stake. A highly trained painter sketches a series of stimuli, having been given certain task instructions: Some stimuli attract more attention; some contain more interesting details; some have been placed into relations that have a better fit in the overall composition; some have obviously been produced by geniuses; some are more challenging to sketch. In short, sketching accuracy reflects a multifaceted psychological process in which a very complicated and

highly trained organism does a very complicated task.

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